Programmatic System Impact Study for Generators and Canadian Import in the I-5 Corridor

Performed for Bonneville Power Administration
Transmission Business Line

PowerWorld Corporation

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Forward

BPA received numerous transmission requests via the Open Access Transmission Tariff (OATT) process from proposed new generators and Canada after November 2000. The requests are publicly available in a queue list on the BPA OASIS. The earliest requests are considered "high" in the queue. The later requests are considered "low" in the queue. Previous System Impact Studies were performed on an individual first come, first serve basis. Separate reports were issued for each. Completion time for requests low in the queue was forecasted to be very lengthy with the allotted internal staff resources.

A new method is being tried to simultaneously meet the intent of System Impact Studies and provide many requestors low in the queue with information sooner, rather than later. The new method performs studies for many generators. The information is documented in fewer reports.

The new method has advantages. Information is provided sooner for the customer's business decisions. Potential transmission system design needed to provide firm service for high levels of new generation is discovered.

The new method has a disadvantage. The amount of new generation added to the model, combined with existing generation, exceeds the load and export capability for most hours during the year. The result is possibly an inaccurate model for generators low in the request queue, due to the need to displace generation that may not actually be displaced in the future. Generators low in the queue may also be provided with information that quickly becomes out of date. This could occur if some generators higher in the queue withdraw their requests.

This PowerWorld report is one of two reports issued simultaneously that apply the new method. All generators that submitted their request for the delivery component of transmission service prior to June 1, 2001 are addressed in one of the two reports. The PowerWorld report addresses proposed generators co-located with the major Pacific Northwest load centers, also commonly referred to as the I-5 corridor. The proposed generators outside of the I-5 corridor are addressed in the BPA report titled "System Impact Study for Transmission Requests from Proposed East Side Generators".

The base network model PowerWorld used for the study is a modified model of the publicly available basecase for the previously completed System Impact Studies at Everett Delta (Snohomish), Satsop, and Longview. The Longview System Impact Study, posted in April 2001, was the last report to address delivery of west side generation. It concluded that potential major system expansion is needed. One option is a Paul to Troutdale 500kV line. This potential line is included as one of four important base network assumptions for PowerWorld's west side study.

In the time between completion of the Longview System Impact Study and the start of PowerWorld's study, BPA made key infrastructure addition decisions. BPA transmission staff resources will be focused on implementing nine priority infrastructure additions known as the "G-9". The priority I-5 corridor projects include a Monroe-Echo Lake 500kV line and a Kangley-Echo Lake 500kV line. Another priority project affecting the I-5 corridor generation is the Schultz-Hanford area 500kV line. PowerWorld added these three additional assumptions in the model. The Paul-Troutdale 500kV line, or alternative, is presently not included in the highest priority infrastructure addition list. It is included in base assumption, due to the results of the Satsop and Longview System Impact Studies.

BPA provided several study objectives to PowerWorld. These objectives are: (a) identify transmission limits for a range of generation patterns that will prevent the long term firm service for proposed generators in request queue order, (b) identify the scope of system expansion to mitigate the identified limits assuming Remedial Action Schemes (RAS) apply only for common mode outages and exclude RAS for single line outages, and (c) identify the reduced magnitude, if any, of the needed system expansion if RAS is optimally included in the system design to minimize transmission line additions. The intent of objective "b" is to identify the upper bound of potential transmission line additions. This could be an indicator of the system design needed to provide margin that could reduce the magnitude and duration of curtailments during summer maintenance outages.

BPA instructed PowerWorld to focus on the conceptual "point A to point B" needs for potential new lines, and to add the assumed specific "point A to point B" system expansion alternatives in the model as needed, regardless of possible environmental or commercial implementation issues. The basic goal of the System Impact Study is to identify the approximate scope of a technical alternative that will mitigate limits in the model. Additional technical alternatives and new transmission line corridor issues are to be addressed in the System Facilities Study phase of the OATT process and the NEPA process, not the System Impact Study phase.

BPA also instructed PowerWorld to assume the proposed generation is interconnected radially into the nearest BPA main grid substation. The primary goal of the System Impact Study is to address delivery of the power across the system. The issues related to interconnection and receipt of the power are to be addressed in the Interconnection Facilities Study, which is another phase of the OATT process.

Although transmission requests across the BPA network from Canada are not from proposed new generators, the PowerWorld study addresses the delivery of the Canadian import by modeling it as a radial generator at the Canada-USA border at Blaine. The total requested amount, added to the existing commitments, exceeds the rating of the Canada-USA intertie. An increase in the intertie capability will need to be a separate study process.

The PowerWorld report follows the BPA instructions and achieves the basic information objectives. Example system expansion needs are identified for each generator. The Executive Summary provides concise information on these findings. The next major step in the OATT process is to perform the System Facilities Study to determine the plan of service for delivery of the generation. The scope could significantly change from the description in the PowerWorld report if proposed generators withdraw their transmission requests. Concurrently with the System Facilities Study, an Interconnection Facilities Study will be needed to determine the interconnection plan of service.

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Executive Summary

The Bonneville Power Administration Transmission Business Line (BPAT) maintains a queue for the evaluation of long-term firm transmission services. The large number of requests in this queue and their interdependence determined the convenience of using a programmatic approach for system impact studies of new generation located in the I-5 corridor.

BPA built an initial case for the summer 2003 peak scenario and established a sequence of requests that was incrementally analyzed by PowerWorld Consulting. The incremental simulation was based on operational system "states", which modeled the proposed new generation, the displaced generation in the Eastern region and worst-case generation patterns.

The initial part of this study evaluates the system impact of the proposed generation, and identifies system expansion at the level to avoid remedial action scheme for the single contingency. Nonetheless, common mode contingencies are also investigated. For each state, several expansion alternatives were tested for simultaneous uses under contingency conditions. The best system expansion alternative determined at a given state was incorporated to the model and considered part of the base case for the next state.

The results of the incremental simulation indicate that substantial system expansion is required to accommodate new generation in the I-5 corridor. Most of the requests included in this study contribute to the North to South and West to East flow, and require at least 230kV expansion.

Two new 230kV lines, Allston to Ross and Allston to St. Marys, and the upgrade of the Longview and Dayton transformers are required for new generation at Allston (request 333) and Paul (requests 354, 356, 358 and 358). RAS can handle the 600MW level at Custer (requests 366 and 367) but a new Custer to Monroe 500kV circuit is needed for the 1200MW level (request 391).

It is convenient to include the 700MW of Alcoa generation (requests 392 and 393) in a new substation located at 2/3 of the planned Paul to Troutdale line. In addition, the Troutdale transformer needs to be upgraded. New generation at Satsop (1300MW of requests 410 and 411) needs a new Olympia to Satsop 230kV circuit and a new Allston to Pearl 500kV line.

No system expansion is needed for the 100MW of Cowlitz generation (request 413).

It is convenient to move the Sedro generation (request 416) to a new substation located at 40/87 of a Custer to Monroe circuit. Sedro generation also requires a new Monroe to Echo Lake 500kV circuit and a new Tacoma to Paul 500kV line. Tacoma generation (request 434) requires the previously mentioned Tacoma to Paul 500kV line.

Santiam generation (request 435) requires a new Santiam to Fry 230kV line for the 600MW level and the upgrade of the Ostrander to Big Eddy 500kV line to 1500MVA. This system expansion together with the upgrade of the Keeler transformers handles additional 570MW at Santiam (request 441). A worst-case pattern for this generation increases the N/S flow and requires two new phase shifters Lexington to Woodland and Cardwell to Merwin.

Additional 1600MW at Custer (requests 451 to 454) would require a 500kV link from Custer up to Big Eddy. An equivalent DC project from Custer to Celilo was also determined as a convenient alternative for the incremental generation level. This DC line needs to carry at least 900MW.

The 170MW level at Trojan (request 457) needs the upgrade of the Clatsop to Astor TP transformer. The 700MW level requires the Allston to Pearl 500kV line derived from Satsop generation in place and a new Pearl to Marion 500kV circuit. A new 115kV line Huber to Tigard 2 and the upgrades of the Huber to Huber 1 to 225MVA and the Huber 2 to Tek 1 115kV line to 200MVA are required.

If RAS is considered in the analysis, then many of these system expansions may not be necessary. Several however will still be required. The following transmission additions represent a minimal amount of additions to support this generation.

- A new 230 kV line from Allston-St Marys.
- Upgrade of Longview 230/115 kV transformer from 288 to 350MVA
- New 230 kV line from Olympia to Satsop
- Huber 2 to Tek 1 115 kV line must be upgraded to 200 MVA
- Line Custer to Sedro 230kV must be operated normally open.

- New Tacoma - Paul 500 kV line, a New Allston - Pearl 500 kV line, and a new Custer - Monroe 500 kV line

  OR

  Custer - Big Eddy path (500 kV or DC line)

In conclusion, considerable system expansion is needed to support the proposed generation in the I-5 corridor without RAS for the single contingency.

1. Background and Objectives

Bonneville Power Administration's Transmission Business Line (BPAT) maintains a long-term firm request queue, available at:

http://www.transmission.bpa.gov/OASIS/BPAT/oasis_html/ltreq.htm

Each request specifies the commencement day, duration, Point of Receipt (POR), Point of Delivery (POD), amount of generation and identity of the requestor. Most of the service requests are Point to Point (PTP) Long Term Firm Transmission services. Each request must be processed to determine the impact of new generation in BPA's transmission system. This is achieved by means of a System Impact Study (SIS) of the new generation. Due to the large number of requests, BPAT determined an incremental approach for the analysis of requests, which has the following objectives:

a) Determine if Available Transfer Capability (ATC) will exist without system expansion.
b) If not, identify the need and approximate scope of a subsequent System Facilities Study (SFS), and determine the scope of the system design to avoid remedial action for the single contingency.
c) Determine the scope of system design with planned generator tripping or ramping, up to the 2900 MW level, and find the optimal generator tripping or ramping combination with new generation added. This objective is addressed separately.

As of June 2001, BPA completed SIS for the Everett Delta, Satsop, and Longview generation projects. Corresponding reports suggested transmission expansion alternatives and some of those were incorporated in the base case for this incremental study. In addition, the reports provided background information regarding the scope and methodology of the system impact study as well as system operating practices.

Based on the geographic location of the requests, BPA determined those to be incorporated in this I-5 corridor study and the corresponding order for their analysis. New requests that appeared in the queue and were located in the I-5 corridor area during the execution of this project were incorporated to this study.

2. BPA System

2.1 System Specification

For this incremental study, the *original system* is defined as BPA's summer 2003 peak case, with Everett Delta, Satsop, and Longview generation and their corresponding system expansion alternatives included in the model. System Impact Studies (SIS) for these generation projects are available at the ftp sites:

ftp://ftp.bpa.gov/outgoing/everettdelta

ftp://ftp.bpa.gov/outgoing/satsop

ftp://ftp.bpa.gov/outgoing/longview

The Longview SIS concluded that significant system expansion was required to accommodate the simultaneous transmission uses. One of the alternatives suggested in the System Facilities Study (SFS) is an 82-mile 500kV line from Paul to Troutdale. BPA is also proceeding with the project of a new 62-mile Monroe to Echo Lake 500kV. Finally, a new 59-mile 500kV line from Schultz to Hardford is being planned. These three lines are modeled in the original BPA system.

This study considers compliance with the following operating practices:

a) The total flow through the Ingledow to Custer lines must be equal to 1600MW. This is achieved by phase shifter control.

b) The total generation in the Grand Coulee and Chief Joseph has to be equal to 7300 MW. This is achieved by displacing hydro and thermal generation in the East region.

2.2 Power Flow Analysis

A power flow simulation for the original case reveals several thermal and voltage violations:

Line Thermal Limit Violations: Original system							
From #r	Name	To Number	To Name	Ckt	Used	Limit	% Limit
40243	CLATSOP	45011	ASTOR TP	1	95.9	94.0	102.0
60810	CANAL	60811	CANAL	1	20.7	20.0	103.4

The Canal transformer is outside the BPA area; thus, it is not longer monitored. A 120MVA rating is assumed for the Clatsop transformer.

Bus low voltages are defined as those below 0.9 p.u., and high voltages as those above 1.1 p.u. The only low voltage violation was found at Wells (0.89 p.u.). Bus low voltages are indicators of deficiencies in the system's compensation or possible collapse problems. Although no system change is proposed for this condition, proximity to static voltage collapse and low voltages are monitored in this study. If the conditions become dangerous with the new generation, alternatives will be proposed.

Bus High Voltage Violations: Original system

Number	Name	Area Name	Monitor	Limit Group	PU Volt	Nom kV	Volt (kV)
50323	DMR132	B.C.HYDR	Yes	Default	1.11902	132.00	147.711
38100	SPICER	PG AND E	Yes	Default	1.11851	21.00	23.489
62013	TOWN1	MONTANA	Yes	Default	1.11252	500.00	556.261
62012	TOWN2	MONTANA	Yes	Default	1.11252	500.00	556.261
45056	DUMMY191	NORTHWES	Yes	Default	1.10819	500.00	554.094
54620	WABASCA	TRANSALT	Yes	Default	1.10754	240.00	265.809
40698	DUMMY97	NORTHWES	Yes	Default	1.10747	500.00	553.734
54285	LEISMER	TRANSALT	Yes	Default	1.10732	240.00	265.756
40453	GAR2EAST	NORTHWES	Yes	Default	1.10420	500.00	552.102
40451	GAR1EAST	NORTHWES	Yes	Default	1.10420	500.00	552.102
54621	MITS E.	TRANSALT	Yes	Default	1.10313	240.00	264.751

High voltages correspond to generating buses with large injections of reactive power or terminals of tap changing transformers. These elements are monitored throughout this study to identify if they get even higher.

2.3 Contingency Analysis

2.3.1 Contingency List

Contingency analysis identifies security violations by solving a power flow for a post contingency condition. Since a full AC power flow solution is obtained, contingency analysis determines thermal violations, low and high bus voltages. Violations are reported if the flow in lines is greater than 100% of its rating, and if bus voltages are either below 0.9 p.u. or above 1.1 p.u.

This study considers the analysis of both single element and common mode contingencies. Single contingency include outages of one transmission line, transformer or generator. Common mode contingencies may include the disconnection of several of these elements. Although operational practices tend to include Remedial Action Schemes (RAS) for severe contingencies, this part of the study evaluates system expansion without modeling RAS. BPA provided the common mode contingencies and PowerWorld generated the single contingency list. The common mode contingencies are stored in the Simulator file CMCAs00.aux. It includes 387 contingencies. The single line contingency list is stored in the Simulator file SCAs00.aux and it contains about 3600 contingencies.

2.3.2 Contingency Results for the Original System

Contingency analysis results for the original case revealed several violations both inside and outside the BPA area. It was established that contingency analysis should focus only on the violations created by the new requests with the associated generation patterns. The following table presents the most severe contingencies that affect the elements in the I-5 corridor, sorted by number of violations. For each contingency, the table shows the number of violations, as well as the maximum overload among those violations created by that contingency.

Severe Contingencies: Original System

Contingency Label	Violations	%Max Line
L/D CUSTER-INGLEDOW 1&2	39	397.8
B/D BONNVILE 230 BFR 1 - ROSS #1 LINE	25	379.3
L/D CUSTER-MONROE 1&2 (S-N FLOW)	17	151.7
B/D TROUTDAL 230 BF2, W BUS	8	125.1
B/D TROUTDAL 230 BF3, W BUS,LINN LINE	8	122.2
L/D CUSTER-MONROE 1&2 (N/S FLOW)	7	124.1
L/D ALV-MAR & LANE-MAR 500	7	131.4
B/D TROUTDAL 230 BF4, W BUS, GRES LINE	6	143.2
L42135TEXACOE-42188WILSNTPC1	5	129.6
L/D JOHN DAY-BIG EDDY 1&2	5	143.0
L/D KEELER-PRL 500 & SHER-CARL 230	4	105.6
L42081SCHUETT-42020SUMASCGC1	4	278.9
L42007LYNDEN-42081SCHUETTC1	4	257.6
BF 4283 KEELER-PEARL-OSTRNDER	4	115.2
L/D KEEL-PRL 500,CASCADTP-SHERW	4	105.6
L46403BOTHELL-46421DIABLOC2	4	111.7
L46403BOTHELL-46421DIABLOC1	4	111.7
L46403BOTHELL-46421DIABLOC3	4	111.7
BF 4448 HANFORD-OSTRANDER-TROUTDAL	3	108.2
L45390F.VALLEY-45281STJOHNTC1	3	178.6

A crossed analysis of overloads versus contingencies reveals the following as the network elements that presented severe violations.

Severe Violations: Original system									
From Number-Name		To Number-Name		Ckt	Xfrmr	Violations	Max %	Zone Name
43707	HUBER 2	43741	TEK 1	1	No	15	112.87	Portland
45141	HOLLADAY	45167	KNOTT	1	No	14	143.20	Pacifico
43029	BEAVRTON	43145	DENNY	1	No	7	111.51	Portland
43041	BETHEL T	40939	SANTIAM	1	No	6	118.92	Portland
40601	KEELER	40599	KEELER	1	Yes	5	104.76	Portland
46403	BOTHELL	46421	DIABLO	1	No	4	108.94	Seattle
46403	BOTHELL	46421	DIABLO	2	No	4	108.94	Seattle
46403	BOTHELL	46421	DIABLO	3	No	4	108.94	Seattle
47176	JOE AST	47214	RUNYAN	1	No	3	194.33	Clark Co
41205	FISHERS	47176	JOE AST	1	No	3	187.54	Clark Co
40899	ROSS	41161	WOODLAND	1	No	3	101.28	Clark Co
42106	MARCH PT	42181	SHELL 2	1	No	3	109.06	SKAGIT
43145	DENNY	43423	PROGRESS	1	No	3	102.41	Portland
40115	BINGEN	45057	CONDITPH	1	No	3	122.20	Portland
45167	KNOTT	45165	KNOTT	1	Yes	3	102.55	Pacifico
45378	BLOSS	45281	ST JOHNT	1	No	3	104.49	Pacifico
45227	OUTLOOK	45283	SUNYSIDE	1	No	3	132.21	Pacifico
40671	LONGVIEW	40669	LONGVIEW	1	Yes	3	105.15	Portland
40599	KEELER	40597	KEELER	1	Yes	3	112.65	Portland
45167	KNOTT	45165	KNOTT	1	Yes	3	102.55	Pacifico
45735	NORTHMTN	41327	SNOH S1	1	No	3	108.46	Snohomis
46431	GORGE	45735	NORTHMTN	1	No	3	111.68	Seattle
45127	HARRISON	45141	HOLLADAY	1	No	3	122.20	Pacifico
42008	KENDALL	42073	NUGENT	1	No	2	270.65	WHATCOM
43215	GRESHAM	45303	TROUTPP2	1	No	2	106.82	Portland
42105	MARCHPT	42174	PETHCORN	1	No	2	138.25	SKAGIT
45069	CRAGVIEW	45337	WEED JPS	1	No	2	152.95	Pacifico
42321	HRNCHTAP	42100	SEDRO	1	No	2	134.51	N.KING
42168	HICKOX T	42170	MTVERNON	1	No	2	123.56	SKAGIT
42180	SHELL 1	42183	TEXTAP1	1	No	2	109.03	SKAGIT
40767	MURRAY	42103	SEDRO NT	1	No	2	151.65	Seattle
42008	KENDALL	42020	SUMAS CG	1	No	2	278.93	WHATCOM

The table shows for each element, the number of contingencies that created overloads, the maximum overload among those contingencies, the element zone name and an indication of whether the element is a line or a transformer. This crossed analysis enables the identification of limiting contingencies and limiting elements. Thus, it is used intensively during system expansion design in order to identify mechanisms for overloading relief.

A detailed analysis of the severely overloaded elements follows: The Huber 2 to Tek 1 line presents overloads for the following single contingencies:

Contingencies that Overload Huber 2 to Tek 1				
Label	Category	Value	Limit	Percent
B/D TROUTDAL 230 BF4, W BUS, GRES LINE	Branch Amp	895.34	793.23	112.87
B/D TROUTDAL 230 BF2, W BUS	Branch Amp	878.95	793.23	110.81
B/D TROUTDAL 230 BF3, W BUS,LINN LINE	Branch Amp	877.77	793.23	110.66
BF 4283 KEELER-PEARL-OSTRNDER	Branch Amp	864.96	793.23	109.04
L/D PRL-KEEL 500 & PRL-SHER 230	Branch Amp	855.73	793.23	107.88
*L40601KEELER-40827PEARLC1	Branch Amp	855.72	793.23	107.88
*X43348MURRAYH-43347MURRAYHC1	Branch Amp	848.89	793.23	107.02
BF 4448 HANFORD-OSTRANDER-TROUTDAL	Branch Amp	843.99	793.23	106.40
*L43029BEAVRTON-43347MURRAYHC1	Branch Amp	842.10	793.23	106.16
*L43348MURRAYH-43541STMARYSC1	Branch Amp	839.93	793.23	105.89
L/D KEEL-PRL 500,CASCADTP-SHERW	Branch Amp	837.72	793.23	105.61
L/D KEELER-PRL 500 & SHER-CARL 230	Branch Amp	837.72	793.23	105.61
BF 4280 KEELER-PEARL-MARION	Branch Amp	834.00	793.23	105.14
L/D OSTRANDER-TROUTDALE 500	Branch Amp	810.95	793.23	102.23
BF 4439 BIG E-OST-TROUT	Branch Amp	808.01	793.23	101.86

In this table single contingencies are tagged with “*”. Even though the overloads are not critical, it is clear that this line would work beyond its thermal limit for a considerable number of contingencies. System expansion plans should consider upgrading this line. We assume that the 158MVA rating is upgraded to 180MVA.

The Holladay to Knott line presents overloads with the following contingencies:

Contingencies that Overload Holladay to Knott				
Label	Category	Value	Limit	Percent
B/D TROUTDAL 230 BF4, W BUS, GRES LINE	Branch Amp	1289.02	900.16	143.20
B/D TROUTDAL 230 BF2, W BUS	Branch Amp	1125.82	900.16	125.07
B/D TROUTDAL 230 BF3, W BUS,LINN LINE	Branch Amp	1100.38	900.16	122.24
BF 4283 KEELER-PEARL-OSTRNDER	Branch Amp	974.32	900.16	108.24
BF 4448 HANFORD-OSTRANDER-TROUTDAL	Branch Amp	973.67	900.16	108.17
L/D KEEL-ST M-TROJ1	Branch Amp	957.06	900.16	106.32
L/D PRL-KEEL 500 & PRL-SHER 230	Branch Amp	946.35	900.16	105.13
*L40601KEELER-40827PEARLC1	Branch Amp	946.10	900.16	105.10
B/D BONNVILE 230 BFR 2 - ROSS #2 LINE	Branch Amp	937.76	900.16	104.18
L/D KEEL-PRL 500,CASCADTP-SHERW	Branch Amp	928.69	900.16	103.17
L/D KEELER-PRL 500 & SHER-CARL 230	Branch Amp	928.69	900.16	103.17
L/D BONN-TROUT #1&2	Branch Amp	910.70	900.16	101.17
*L/D OSTRANDER-TROUTDALE 500	Branch Amp	909.56	900.16	101.04
BF 4280 KEELER-PEARL-MARION	Branch Amp	904.74	900.16	100.51

The common mode contingencies at Troutdale considerably overload this element. Line upgrade is necessary to support the Keeler to Pearl 500kV single line outage. The loading in this element is decreased by opening the Urban to Canyon 115kV line. This would also decrease the base case flow in Holladay to Knott from 161MW to 122MW. An alternative is to upgrade this line from 235 to 300MVA. It is assumed in this study that the Urban to Canyon 115kV line is sectionalized.

The Beaverton to Denny 115kV line presents overloads for the following contingencies:

Contingencies that Overload Beaverton to Denny

Label	Category	Value	Limit	Percent
B/D TROUTDAL 230 BF4, W BUS, GRES LINE	Branch Amp	1102.86	989.03	111.51
B/D TROUTDAL 230 BF2, W BUS	Branch Amp	1083.38	989.03	109.54
B/D TROUTDAL 230 BF3, W BUS,LINN LINE	Branch Amp	1082.18	989.03	109.42
BF 4448 HANFORD-OSTRANDER-TROUTDAL	Branch Amp	1019.78	989.03	103.11
*L/D OSTRANDER-TROUTDALE 500	Branch Amp	991.51	989.03	100.25
BF 4439 BIG E-OST-TROUT	Branch Amp	990.69	989.03	100.17
*X43527SHERWOOD-43525SHERWDBC1	Branch Amp	990.25	989.03	100.12

As the overloads for the single contingencies are small, no upgrade is assumed.

The Bethel T to Santiam 230kV line presents overloads for the following contingencies:

Contingencies that Overload Bethel T to Santiam

Label	Category	Value	Limit	Percent
L/D MCL-OST-PRL,BE-CHM,BE-MCL-MON	Branch Amp	1070.21	899.91	118.92
B/D MCLOUGLN 230 BF - FAULT ANY LINE	Branch Amp	993.50	899.91	110.40
L/D JOHN DAY-BIG EDDY 1&2	Branch Amp	976.12	899.91	108.47
L/D MCL-OST 500,MCL-MON	Branch Amp	970.97	899.91	107.90
L/D B.E.-MCL-MONITOR	Branch Amp	955.21	899.91	106.14
*L43313MCLOUGLN-43329MONITORC1	Branch Amp	954.71	899.91	106.09

The McLaughlin to Monitor line causes an overload of 6.09% in this element. We consider that future system expansion addresses the effect of this contingency.

The Keeler 500 to 230kV transformer is overloaded with the following contingencies:

Contingencies that Overload the Keeler Transformer

Label	Category	Value	Limit	Percent
BF 4283 KEELER-PEARL-OSTRNDER	Branch MVA	995.25	950.00	104.76
L/D KEEL-PRL 500,CASCADTP-SHERW	Branch MVA	958.29	950.00	100.87
L/D KEELER-PRL 500 & SHER-CARL 230	Branch MVA	958.29	950.00	100.87
L/D PRL-KEEL 500 & PRL-SHER 230	Branch MVA	952.15	950.00	100.23
*L40601KEELER-40827PEARLC1	Branch MVA	951.62	950.00	100.17

The Keeler to Pearl single contingency slightly overloads the transformer. As the loading of that transformer may increase due to the North to South flow, it is possible that this element presents overloads when new generation is modeled in the I-5 corridor. No upgrade of this transformer is assumed in the original case.

The three Bothell to Diablo 230kV circuits present 10% overloads for the corresponding single circuit outages. The flow to Diablo is unlikely to be affected by new generation in the I-5 corridor, but these elements must be monitored due to the size and location of the new generation at Custer. No upgrade of this element is assumed. Ongoing expansion projects outside this study would correct this limitation.

Overloads in the Joe Ast to Runyan 115kV line are due only to common mode contingencies in the Bonneville S/E.

The Ross to Woodland 230kV line becomes overloaded with the following common mode contingencies. No system expansion is assumed.

Contingencies that Overload Ross to Woodland

Label	Category	Value	Limit	Percent
B/D BONNVILE 230 BFR 1 - ROSS #1 LINE	Branch Amp	1083.85	1070.11	101.28
L/D ALLST-TROJ2,ALLST-KEEL 500	Branch Amp	1078.76	1070.11	100.81
L/D ALLST-TROJ1,ALLST-KEEL 500	Branch Amp	1077.79	1070.11	100.72

The Knot 115 to 59kV transformer is overloaded with the following contingencies:

Contingencies that Overload the Knott Transformer

Label	Category	Value	Limit	Percent
*X41019STJOHNS-41017STJOHNSC1	Branch MVA	128.19	125.00	102.55
*L43783SCHNITZ#-41017STJOHNSC1	Branch MVA	127.88	125.00	102.31
B/D ST JOHNS 115 BF	Branch MVA	127.15	125.00	101.72

All the listed contingencies overload the transformer slightly. We will assume that the 125MVA rating of this transformer can be upgraded to the 150MVA level.

The North Mountain to Snohomish 230kV line presents an overloaded of 8% when any of the Bothell to Diablo circuits is disconnected. The same contingency creates an 11% overload in the Gorge to North Mountain 230kV line. No upgrade of those circuits is considered.

The following common mode contingencies overload the Harrison to Holladay 115kV line. No upgrade of this element is considered.

Contingencies that Overload Harrison to Holladay				
Label	Category	Value	Limit	Percent
B/D TROUTDAL 230 BF4, W BUS, GRES LINE	Branch Amp	1100.04	900.16	122.20
B/D TROUTDAL 230 BF2, W BUS	Branch Amp	936.92	900.16	104.08
B/D TROUTDAL 230 BF3, W BUS,LINN LINE	Branch Amp	911.49	900.16	101.26

The Kendal to Nugent 115kV line presents overloads for the following single contingencies:

Contingencies that Overload Kendall to Nugent				
Label	Category	Value	Limit	Percent
*L42081SCHUETT-42020SUMASCGC1	Branch Amp	625.05	230.94	270.65
*L42007LYNDEN-42081SCHUETTC1	Branch Amp	575.64	230.94	249.26

When the path Sumas-Schuett-Lynden is opened, the alternative path Sumas-Kendall-Nugent-Britton-Bellingham becomes severely overloaded. The generation at Sumas CG is independent of the proposed generation in the I-5 corridor. This contingency currently includes actions to mitigate security violations.

The Gresham to TroutPP2 230kV line is overloaded with the following contingencies:

Contingencies that Overload Gresham to TroutPP2				
Label	Category	Value	Limit	Percent
*L41093TROUTDAL-45301TROUTPP1C1	Branch Amp	1181.45	1106.00	106.82
*L43291LINNEMAN-45301TROUTPP1 C1	Branch Amp	1127.06	1106.00	101.90

An investigation of these violations suggests that they may be a result of large flows in the new Paul to Troutdale 500kV line included in the model. This element tends to drive more flow to the East of Portland, sending more power through the 230kV system South of its receiving end. We assume that the Gresham to TroutPP2 230kV is upgraded from a 440 to a 500MVA rating.

The Evergreen to Sifton outage overloads the Sifton to SW100 115kV line in 12% and vice-versa. These are parallel circuits to a load. Thus, this contingency is not affected by the new generation.

The F.Valley to St. Johns creates the following overloads:

F.Valley to St. Johns Outage Violations			
Element	Value	Limit	Percent
FROM F.VALLEY TO HZLDLPPL CKT 1	239.45	134.10	178.56
FROM HZLDL CC TO ROSS CKT 1	208.18	150.80	138.05
FROM ST JOHNS TO ST JOHNS CKT 1	252.00	228.00	110.53

This occurs since an outage of the St. Johns to F. Valley leaves the mentioned line as part of the way out for River Road C generation. These violations will not be affected by the new generation in the I-5 corridor. However, it is convenient to upgrade the following path:

Path to be Upgraded								
From Number	From Name	To Number	To Name	Circuit	R	X	C	Lim A MVA
47171	HZLDL CC	40897.00	ROSS	1.00	0.00196	0.01026	0.0016	150.8
47171	HZLDL CC	45399.00	HZLDLPPL	1.00	0	0.0003	0	298.8
45390	F.VALLEY	45399.00	HZLDLPPL	1.00	0.00439	0.0198	0.0027	134.1

By means of a 115kV line from Ross to F.Valley with per unit parameters: R=0.00635, X=0.03036 and C=0.0043. We assume this line has a 300MVA limit.

Finally, the Pearl to Ostrander 500kV line needs to be upgraded to the 2400 MVA since for several contingencies this is the alternative path from the 500kV system West of Portland to South and East regions.

There are other contingencies, mostly common mode, which create a single violation. Alternatives to mitigate these violations are not discussed in this study. Since these violations must not become severe when new generation is incremented, the following table is kept for reference.

Additional Violations: Original system								
From Number-Name		To Number-Name		Ckt	Xfrmr	Violations	Max %	Zone Name
42105	MARCHPT	42173	PADILTAP	1	No	1	150.86	SKAGIT
40039	ALFALFA	45229	OUTLOOK	1	No	1	148.40	Lower Co
42108	BAKER SW	42101	SEDRO	2	No	1	128.08	SKAGIT
42108	BAKER SW	42101	SEDRO	1	No	1	128.06	SKAGIT
42161	AVON PMP	42164	BURLIGTN	1	No	1	124.32	SKAGITI
42300	SAMMAMSH	42301	SAMMAMSH	1	Yes	1	120.74	N.KING
45183	LONEPINE	45195	MERIDINP	1	No	1	121.19	Pacifico
42300	SAMMAMSH	42301	SAMMAMSH	2	Yes	1	120.55	N.KING
45017	BALDY SS	45221	OAKKNOLL	1	No	1	119.26	Pacifico
43083	CANEMAH	43081	CANEMAH	2	Yes	1	115.97	Portland
42305	NOVELTY	42311	STILWTRP	1	No	1	115.13	N.KING
45433	ORCHARDW	45277	SELAH	1	No	1	114.80	Pacifico
45317	UNIONGAP	45315	UNIONGAP	1	Yes	1	114.78	Pacifico
42164	BURLIGTN	42175	RITA P	1	No	1	114.53	SKAGIT
45181	LONEPINE	45179	LONEPINE	2	Yes	1	114.24	Pacifico
42310	COTAGEBR	42393	DUVAL	1	No	1	114.01	N.KING
45227	OUTLOOK	45261	PUNKIN C	1	No	1	113.99	Pacifico
40735	MIDWAY B	46069	PRIESTR2	2	No	1	111.23	Lower Co
40735	MIDWAY B	46069	PRIESTR2	1	No	1	111.22	Lower Co
40179	CARLTON	41320	CARLTONT	1	No	1	108.04	Portland

2.4 Summary of Assumptions for the Original System

In addition to the three new lines mentioned in Section 2.1, the following are assumptions for the original system:

Summary of Assumptions for the Original System	
Canal Transformer:	Not Monitored
Clatsop Astor Transformer:	Assume 120MVA rating
Huber 2 to Tek 1:	The 158MVA rating is increased to 180MVA.
Urban to Canyon 115kV:	Line is sectionalized.
Knott 115 to 59kV:	The 125MVA rating is increased to 150MVA
Gresham to TroutPP2 230kV:	The 440MVA rating is increased to 500MVA
Pearl to Ostrander 500kV	Is upgraded to the 2400MVA level
New 115kV line Ross to F.Valley	To solve existing problem
Sammamsh Transformer	Is upgraded to the 450MVA level (see Section 6.10.4)

If these upgrades were not realizable, equivalent system expansion would be needed to improve the reliability level.

The original system model is loaded in the Simulator s00.pwb file, where "s" stands for "state" and the extension ".pwb" stands for the PowerWorld Binary format. A display for the original system is loaded in the Simulator Display file s00.pwd.

With these assumptions in place, there are no thermal violations in the original system and the elements that have their loading between 95 and 100% are:

Elements Loaded Between 95 and 100%: Original system

From Number	From Name	To Number	To Name	Circuit	Monitor	Used Limiting Flow	Limit	Used % of Limit	MVA or Amps?
48131	GARDENSP	40525	HAYFORD	1	YES	287.1	288.2	99.6	Amps
37119	SRWTP	37117	POCKET 2	1	YES	747.6	759.8	98.4	Amps
18001	H ALLEN	18019	H ALLEN	1	YES	290.5	300.0	96.8	MVA
24702	KRAMER	24753	SUNGEN	1	YES	885.0	920.2	96.2	Amps
48035	BENEWAH	48427	TEKOA	1	YES	241.2	252.0	95.7	Amps
43139	DAYTON	43137	DAYTON	1	YES	47.7	50.0	95.5	MVA
18002	HA PS	66280	REDBUTTE	1	YES	477.2	500.0	95.4	Amps
30419	CR1T4_23	30430	FULTON	1	YES	758.0	796.0	95.2	Amps

This list will be used for reference during the incremental simulation. At each state, system expansion will be the necessary to mitigate severe overloads and keep the number of elements within this range comparable.

3. Incremental Sequence and System States

Based on the Long Term Firm Request Queue, BPA determined the requests to be included in this study. Some of these requests will be rejected, others will be approved and corresponding System Facilities Studies will be developed. As several generation projects are required to cover BPA's generation requirements in the I-5 corridor for 2003, the effect of incorporating each new generation is interdependent. BPA determined that the incremental approach captures informational aspects of the market, the effect of each new generation in the system, and simultaneous uses. The Incremental Sequence of Requests, which is here called "the sequence" was determined based on the proximity in the long-term queue and their status. The following table shows the incremental sequence used in this programmatic analysis.

Incremental Sequence of Requests

State Number	Quantity	Point of Delivery		Request #
	MW	S/E	Voltage	
0. Original system				
1.	520	Allston	230kV	333
2.	300	Paul	500kV	354,6,8,9
3.	600	Custer W	230kV	366,7
4.	600	Custer W	500kV	391
5.	700	Alcoa	230kV	392,3
6.	1300	Satsop	500kV	410,11
7.	100	Cowlitz	115kV	413
8.	600	Sedro	230kV	416
9.	250	Tacoma N	230kV	434
10.	600	Santiam	500kV	435
11.	570	Santiam	500kV	441
12.	1600	Custer W	500kV	451-4
13.	170	Trojan	230kV	457
14.	700	Trojan	230kV	459,60

In the previous table, the state number specifies the requests included in the model up to that point. For instance, state 3 includes generation at Allston, Paul and Custer, after requests #333, 354, 356, 358, 359, 366 and 367. The 16 states result in corresponding models that include all the requests considered in the previous states and the new generation for that state. For simplicity, requests that were close in the queue and had the same POD were included in a single state. State 0 corresponds to the original system with the assumptions described in Section 2.4. Subsequent states include increments due to the new generation as well as the derived system expansion.

New generation South of the Paul to Raver 500kV line may be beneficial to the reliability of the system in some regions of the I-5 corridor. In order to simulate possible hidden conditions, different generation patterns are analyzed to determine worst-case conditions. The generation displacement specification for all the states is shown in the table below. We see that at each state new generation in the I-5 corridor enters the model and corresponding generation in the East BPA region is displaced to balance generation. Other considerations related to generation displacement are discussed in Section 4.

The operability of the generation at Centralia and Chehalis is managed to create worst-case generation patterns for each state. This makes it possible to have a robust system expansion design for a number of conditions. When generation in the displacement sequence is about to be finish, the import/export levels for the BPA area are conveniently changed to create a new displacement base point. This is necessary since for the level of aggregate generation for states twelve and up is considerably large.

Note that the sum of all the generation for several states may differ. This is due to changes in imports/exports in different points of the sequence and changes in the system losses.

Generation Patterns and Displacement

	STATE	0	1	2	3	4	5	6	7	8	9	10A	10B	11	12	13	14
	GENERATION	Output (MW)															
New Generation	40043 ALLSTON	0	520	520	520	520	520	520	520	0	0	0	520	0	520	520	520
	40821 PAUL	0	0	300	300	300	300	300	300	0	0	0	300	0	300	300	300
	40323 CUSTER W	0	0	0	600	1200	1200	1200	1200	1200	1200	1200	1200	1200	2800	1200	1200
	40033 ALCOA	0	0	0	0	0	700	700	700	0	0	0	700	0	700	700	700
	40947 SATSOP	0	0	0	0	0	0	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300
	46607 COWLITZ	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100
	42100 SEDRO	0	0	0	0	0	0	0	0	600	600	600	600	600	600	600	600
	41053 TACOMA N	0	0	0	0	0	0	0	0	0	250	250	250	250	250	250	250
	40941 SANTIAM	0	0	0	0	0	0	0	0	0	0	600	600	1170	1170	1170	1170
	43599 TROJAN 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	170	870
Pattern	41801 CHEH G1	195	195	195	195	195	195	195	195	0	0	0	195	0	195	195	195
	41802 CHEH G2	195	195	195	195	195	195	195	195	0	0	0	195	0	195	195	195
	41803 CHEH ST	230	230	230	230	230	230	230	230	0	0	0	230	0	230	230	230
	45039 CENTR G1	692	692	692	692	692	692	692	692	0	0	0	692	0	692	692	692
	45041 CENTR G2	692	692	692	692	692	692	692	692	0	0	0	692	0	692	692	692
Generation Displacement	43047 BOARD F	540	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	43119 COYO S1	70	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	43111 COYO G1	110	110	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	45135 HERM S	135	135	35	0	0	0	0	0	0	0	0	0	0	0	0	0
	45133 HERM G	295	295	295	0	0	0	0	0	295	45	0	0	0	0	0	0
	47549 RATH G2	265	265	265	0	0	0	0	0	220	220	0	0	0	0	0	0
	48359 RATHGEN1	68	68	68	63	0	0	0	0	68	68	0	0	0	0	0	0
	48361 RATHGEN2	68	68	68	68	0	0	0	0	68	68	0	0	0	0	0	0
	40653 LIBBY	570	570	570	570	100	0	0	0	570	570	300	0	0	590	300	0
	40554 HUNGRY H	294	294	294	294	294	0	0	0	294	294	294	0	0	294	294	0
	40361 DWOR 1	95	95	95	95	95	0	0	0	95	95	95	0	95	95	95	0
	40363 DWOR 2	95	95	95	95	95	0	0	0	95	95	95	0	95	95	95	0
	40365 DWOR 3	225	225	225	225	225	110	0	0	225	225	225	0	225	225	225	225
	40717 MCNARY	22	22	22	22	23	22	0	0	21	21	21	0	21	21	21	21
	40663 LIT GOOS	386	386	386	386	386	386	0	0	386	386	386	0	386	386	386	386
	40677 LOW GRAN	386	386	386	386	386	386	0	0	386	386	386	0	386	386	386	386
	40681 LOW MON	386	386	386	386	386	386	0	0	386	386	386	0	386	386	386	386
	62050 COLSTP 1	315	315	315	315	315	315	305	305	315	315	315	315	315	0	0	0
	62049 COLSTP 2	315	315	315	315	315	315	315	315	315	315	315	315	315	0	0	0
	62048 COLSTP 3	780	780	780	780	780	780	780	780	780	780	780	780	780	0	0	0
	62047 COLSTP 4	780	780	780	780	780	780	780	780	780	780	780	780	780	0	0	0
	40725 MCNARY 1	150	150	150	150	150	150	150	50	150	150	150	0	150	150	150	150
	40727 MCNARY 2	650	650	650	650	650	650	650	650	650	650	650	0	650	650	650	650

4. Methodology

4.1 Per State Analysis

At a given state *s*, corresponding to the system case s01.pwb, s02.pwb and so on, the system has a configuration that includes the generation and the system expansion alternatives defined for all previous states *s*-1, *s*-2, … 0.

At each state *s*, we do the following:

a) The new generation corresponding to requests at that state is connected.

b) Generation in the East region is displaced in order to balance the production.

c) A load flow simulation is performed.

d) Imports from Canada through the Ingledow-Custer link is regulated at 1600MW by means of phase shifter control.

e) Generation at Grand-Coulee and Chief Jo is monitored to be at 7300MW. If this is not the case, generation displacement at the last displaced unit in the sequence is regulated until this value is achieved.

   The resulting system is the base case for state *s*.

f) With the new generation in place, (state) base case violations and the elements loaded in the 95% to 100% range are identified and recorded.

g) If there are (state) base case violations, required system expansion is designed and implemented and contingency analysis is performed over the resulting case. This step is repeated until a robust minimum system expansion is achieved.

4.2 Contingency Analysis

4.2.1 Thermal Limits

At every state, all the single and common-mode contingencies are studied with and without the new generation. If new violations appear during the contingency analysis, system expansion corresponding to the simultaneous conditions not exceeding reliability limits is proposed.

The strategy for assessing limits caused by thermal ratings is described as follows. The new generator at state *s* is modeled assuming a radial connection to the corresponding bus. The contingency analysis is performed for the simultaneous North to South summer conditions. Comparison of results with and without the new generation flag the thermal limit violations caused by the new generation. Power Transfer Distribution Factors (PTDF's) for the flow on the limiting branches in the post-contingency condition (OTDF's) are calculated for every generator in the model. Since away from collapse PTDF's are well-behaved large signal sensitivities, they are considered constant for incremental flow with a specific network topology, regardless of the system loading. A second part of this project uses these factors to determine the generation changes that would eliminate the thermal limit violations. If generator factors show a low sensitivity to the branch flow, the PTDF's are recalculated for every bus in the system model to confirm that the flow is load-based and not due to bulk power transfers. Subsequent power flow studies are performed to validate the linear incremental flow assumption.

The contingencies are ranked based on the number and severity of thermal violations created at state *s*. All severe contingencies in BPA areas are analyzed and all the violations in the I-5 corridor are monitored. Using the full set of contingencies at each state ensures that the overall system reliability level is maintained. A crossed analysis of overloaded elements versus contingencies enables the identification of cause-effect relations and their solution. This enables a robust system expansion design by considering at the same time the severity of the contingency and the weakness of specific network elements.

4.2.2 Voltage Limits

Once the system expansion for thermal limits is designed and implemented in the model, the system is screened for low voltages and voltage stability. The data on generator reactive capability and interconnecting facility assumptions become important during this phase. We assume zero reactive capability for the new generation. The generator added at a given state is assumed to supply the reactive losses of the step up transformer and the interconnecting line delivering the power to the POR. With a minimal system expansion assumption as a worst-case test, the system is screened for low voltage and voltage stability. Transient stability is not part of this study.

4.2.3 Contingency Analysis for Voltage Stability

P-V simulations are used in order to determine voltage stability margins. Generation is incrementally increased and decreased at strategically selected locations to gradually increase power flow across constrained paths, until a voltage stability limit is found for the contingency condition. The transfer is specified from the POD to the displaced generators for that state. If the voltage stability limit is below the thermal limit, the need for system expansion is determined. Potential voltage stability problems are identified in the contingency analysis, when a certain solved contingency without the generation is unable to be solved with the generation in place. These contingencies are studied independently to propose system expansion related to voltage stability.

4.3 System Expansion

4.3.1 Guidelines

The identification of system expansion alternatives and their analysis utilizes the following guidelines:

a) Compliance with the WSCC and NERC system design criteria is assumed. All single and common mode contingencies must be observed for thermal and voltage limits. The desired level of reliability is the one of system expansion that avoids RAS for every single contingency.

b) System expansion will not be planned to accommodate more than the contracted commitments and transmission reliability margin. Actual flow will only exceed the reliability limit in the event of an unplanned outage, and operating actions will be planned and implemented to reduce the flow to levels in accordance with operating criteria.

c) At each state, generation is displaced according to the hydro and thermal displacement sequence provided by BPA, and area interchange is modified to accommodate additional new generation in the I-5 corridor.

d) At each state, area interchange is observed as well as operating policies such as 1600MW in the Ingledow-Custer lines and 7300MW in the Grand-Coulee and Chief Jo area.

e) Long term Total Transfer Capability (TTC) is assumed to be the maximum reliable flow levels demonstrated in the system studies for the condition with all lines in service.

f) When looking at system expansion alternatives, special attention is paid to the loading of underlying lines that are already heavily loaded so that the net increase in flow on these lines is very small, if not decreased.

This study performs extensive analysis of different expansion alternatives per state in an iterative manner. The final system expansion design is verified by repeating the state analysis (load flow and contingency analysis) with the generation and system expansion alternative in place. Alternatives chosen for different states may collapse to a more efficient single alternative. For example, assume that state 1 incorporates two alternatives for system expansion SE.1A and SE.1B. The results in state 2 with these two alternatives may differ and we may have a tree of expansion alternatives. As some of the alternatives in different state s, s+1, s+2 may help the accommodation of transfers in previous states, the analysis attempts to collapse alternatives to obtain the best one according to the sequence. Several iterations are needed to obtain a sequence of states with corresponding robust system expansion design.

4.3.2 Assumptions about POD's that are not Actual Sinks

Transmission service requests may have POD's where the power cannot be consumed, either because of insufficient load or because the load already has more transmission service rights than it can simultaneously use. The intent is to specify a POD where a second transmission service contract will take the power from the requested POD to another POD that is the actual sink. The second transmission service contract may exist with a Transmission Contract Holder (TCH) who will not exercise rights for other generation, or it may not exist and it will be requested in the future with a process that could involve a system impact study. This study assumes a second transmission service request that distributes the load at the POD across actual sinks. In order to model an assumed second transfer request to actual PoD, we displace generation at each state, according to the hydro and thermal generation units in the East part of BPA's system. Interchange is modified to accommodate additional generation, as described in Section 3.

4.3.3 Generator Dropping Requirements

At present, Remedial Action Schemes (RAS) provides the North to South summer transfer capability in the I-5 corridor by dropping generation at several locations. This study considers system expansion strong enough to avoid RAS for the single contingency. A second part of this study performs the analysis considering RAS and a worst-case generation pattern. RAS schemes would allow a generator dropping level of 2900 MW. Single contingencies that currently have an associated Remedial Action Scheme are: Custer-Ingledow #1&#2, Custer-Monroe #1&#2, Monroe-Echo Lake, Raver-Paul, Paul-Allston #1 and #2, Allston-Keeler, Keeler-Pearl (after Chehalis generation is connected). Generation would be dropped at Chief Jo, Grand Coulee, Whitehorn, Fredonia, GM Schrum, Mica, and/or Revelstoke.

5. Summary of Incremental Simulation Results

#	Gen.		Incremental Expansion	Single Contingency	Cause	RAS Alternative
0	Original	0	Canal transformer is not monitored	Base Case	Existing	
			Upgrade Clatsop-AstorTP transformer to 120MVA	Base Case	Existing	
			Upgrade of Huber 2 to Tek 1 180MVA	Keeler to Pearl	Existing	
			Opening of Urban to Canyon 115kV line	Keeler to Pearl	Existing	
			Upgrade of Knott transformer 125 to 150MVA	St. Jonhs transformer	Existing	
			Upgrade Gresham to TrutPP2 230kV to 500MVA	Troutdale transformer	Existing	
			Upgrade Pearl-Ostrander 500kV line to 2400MVA	Keeler to Pearl	Existing	
			Upgrade of Sammamsh transformers to 450MVA	Sammamsh transformer	Existing	
			New 155kV line Ross to F.Valley	Ross to St. Johns	Existing	
1	Allston	520	Upgrade of Dayton transformer from 50 to 60MVA	Allston to Keeler	Allston	YES
			Upgrade of Longview transformer from 288 to 350MVA	Lexington transformer	Allston+Exist.	NO
			New 230kV line Allston to Ross	Allston to Keeler	Allston	YES
			New 230kV line Allston to St. Marys	Allston to Keeler	Allston	NO
2	Paul	300	Upgrade of the new Allston to Ross line	Allston to Keeler	Paul	YES
			Upgrade of Dayton transformer from 60 to 75MVA	Allston to Keeler	Paul	YES
3	Custer	600	RAS	Raver to Paul	Custer	
4	Custer	600	New Custer to Monroe 500kV circuit.	Custer to Monroe	Custer	Uncertain
5	Alcoa	700	New substation at 2/3 of Paul to Troutdale 500kV	Alcoa to Ross	Alcoa	NO
			Upgrade of the 230-500kV Troutdale trafo to 1500MVA.	Ostrander to Troutdale	Alcoa	YES
6	Satsop	1300	New circuit Olympia to Satsop	Base Case	Satsop	NO
			Disconnection of Holcomb to Valley T To solve Cosmopolys to Raymond overload	Base Case	Satsop	Uncertain
			New Allston to Pearl 500kV line.	Keeler to Pearl	Satsop	Uncertain
7	Cowlitz	100	No system expansion is needed.			
8	Sedro	600	New Monroe to Echo Lake 500kV circuit.	Snok Tap to Echolake	Sedro	YES
			New Tacoma to Paul 500kV line	Raver to Paul	Sedro	Uncertain
9	Tacoma	250	The Tacoma to Paul 500kV line of state 8 is needed.	Raver to Paul	Tacoma	Uncertain
10	Santiam	600	New Santiam to Fry 230kV line	Bethel to Fry	Santiam	YES
			New PShift Lexington to Woodland & Cardwell to Merwin	Lexington transformer	I-5	YES
			Upgrade of Big Eddy to Ostrander to 1500MVA	Marion to Pearl	Santiam	YES
11	Santiam	570	Santiam to Fry 230kV line w/rating over 600MVA	Alvey to Marion	Santiam	YES
			Upgrade of the Keeler 230 to 115kV transformers	Keeler transformers	Santiam	YES
12	Custer	1600	Line Custer to Sedro 230kV must be sectionalized.	HRnchTap to Sedro	Custer	NO
			New 500kV path Custer to Big Eddy or DC project Custer to Celilo with 900MW	Several Contingencies SeeTable in 6.12.3	Custer	NO
13	Trojan	170	Upgrade of the Clatsop to Astor TP to 150MVA	Allston to NysTap	Trojan+Allston	YES
14	Trojan	700	New Allston to Pearl line must be in place (state 6)	Allston to Keeler	Trojan	Uncertain
			New 500kV circuit Pearl to Marion	Pearl to Marion	Trojan	YES
			Upgrade of the Huber 2 to Tek 1 to the 200MVA	Muray to St. Marys	Trojan+Allston	Uncertain
			New 115kV line Huber to Tigard 2	Sherwood transformer	Trojan+Allston	YES
			Upgrade of the Huber to Huber 1 to 225MVA	Sherwood transformer	Trojan+Allston	YES

This table presents a summary of the results for all the states specified in Section 3, plus the base case. For each state, the required system expansion is described and justified by the system contingency (or base case) that causes an insecure system condition.

The second–to-last column assigns specific responsibility for the system expansion. In several opportunities, the problems were identified as existing and not related to the I-5 generation. Those cases were assigned to the base case. Problems that occurred as a result of the aggregate new generation were marked as caused by I-5 generation. Finally, there were cases where more than one generator caused the overload and thus the responsibility was shared.

The last column assigns specifies whether Remedial Action Schemes (RAS) are an alternative to the system expansion. This was determined by looking at the ability of RAS to remove the overloads associated with the contingencies. The RAS that can alleviate overloads is described in Section 7.

6. Thorough per State Analysis

6.1 System State 1: Allston Generation (520MW) Request 333

6.1.1 Base Case Results

The 520MW generation at Allston is balanced by decreasing the same amount at Board F. Generation at Grand Coulee remains constant. The phase shifter control for the Ingledow-Custer flow is set up at –20 degrees. The base case did not present new violations. Figure 1.a shows the PTDF contouring for an Allston to Board transfer in the no-contingency case.

Contouring diagrams enable the visualization of the distribution of flows across the system by geographically assigning a level-based color to the displayed elements. A radar color spectrum (shown in the diagram) is utilized to quantify flow levels. Lines that have a PTDF between 0 and 10% are colored green. From 10 to 20% they are colored yellow, and so on. Thus, the transfer has a higher impact on the lines colored pink and less impact on those colored green.

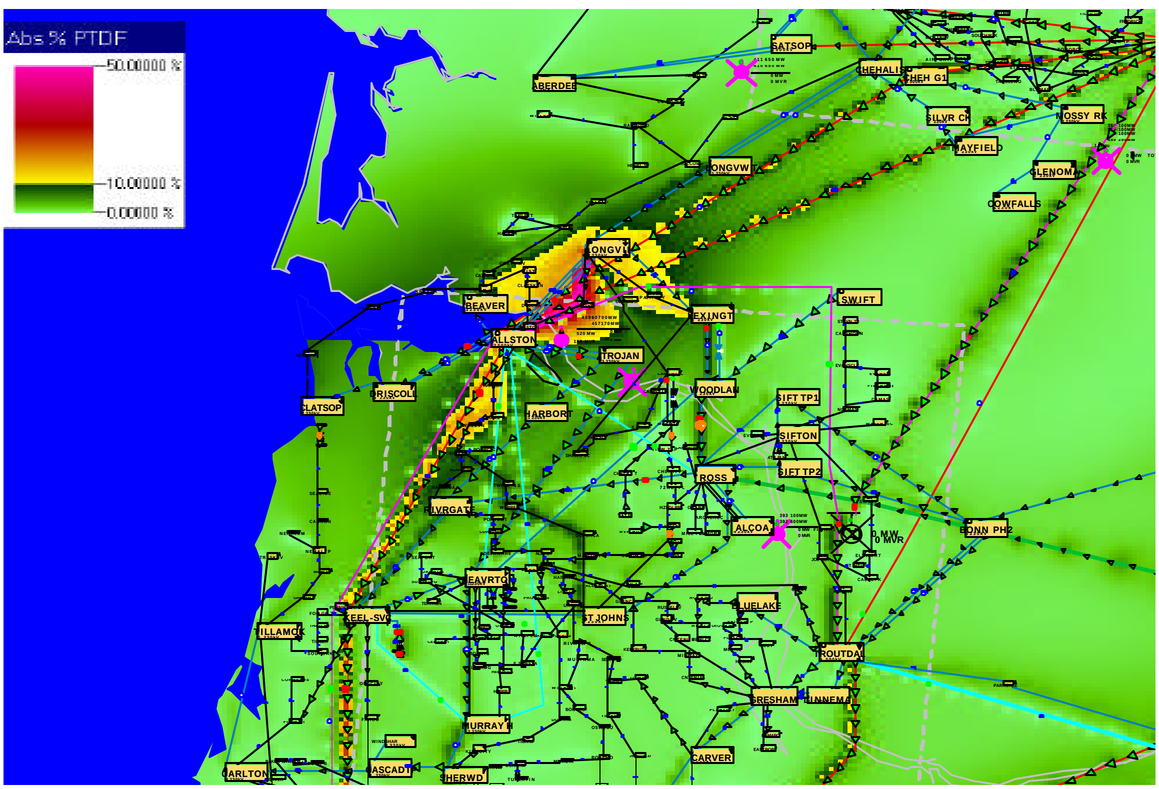

Figure 1.a: PTDF Contouring for Allston to Board F Transfer

The figure shows that around 40% of the flow takes the North 500kV path from Allston (to Chehalis) to Paul and around 20% the South 500kV path from Allston to Keeler to Pearl. The rest of the flow goes across the 230 and 115kV systems. Approximately 10% of the transfer goes through Trojan to St. Marys, 10% reaches St. Johns through the 115kV system and 10% goes through the Ross to Woodland line. Allston generation caused around 50MW additional North to South flow in these 230 and 115kV systems have. This makes it difficult to extract the power out of the Allston substation and new violations to appear in this area for contingency conditions.

6.1.2 Contingency Analysis Results

The following Table lists the most severe contingencies that affect elements in the I-5 corridor. Both single and common mode contingencies are listed.

Severe Contingencies

Contingency Label	Skip	Proc.	Solved	Violations	Max Line %
L/D CUSTER-INGLEDOW 1&2	NO	YES	YES	39	418.9
L/D CUSTER-MONROE 1&2 (N/S FLOW)	NO	YES	YES	19	164.6
L/D CUSTER-MONROE 1&2 (S-N FLOW)	NO	YES	YES	19	164.6
B/D BONNVILE 230 BFR 2 - ROSS #2 LINE	NO	YES	YES	16	329.4
L/D ALV-MAR & LANE-MAR 500	NO	YES	YES	9	138.0
B/D TROUTDAL 230 BF2, W BUS	NO	YES	YES	8	127.8
B/D TROUTDAL 230 BF3, W BUS,LINN LINE	NO	YES	YES	7	128.2
B/D LONGVIEW 115 BF	NO	YES	YES	6	124.5
B/D TROUTDAL 230 BF4, W BUS, GRES LINE	NO	YES	YES	6	129.5
L/D ALLST-TROJ2,ALLST-KEEL 500	NO	YES	YES	6	143.2
L/D ALLST-TROJ1,ALLST-KEEL 500	NO	YES	YES	6	143.5
B/D BONNVILE 230 BFR 3 - BUS	NO	YES	YES	5	148.2
BF 4394 ALLSTON-KEELER-PEARL	NO	YES	YES	4	120.5
BF 4502 PAUL-ALLSTON-KEELER	NO	YES	YES	4	118.5
L/D KEEL-ST M-TROJ1	NO	YES	YES	4	118.1
L40045ALLSTON-40601KEELERC1	NO	YES	YES	4	118.6
L/D MARION-ALV & MARION-SANT 500	NO	YES	YES	4	137.9

To determine the effect of these contingencies, a crossed analysis of overload versus contingencies is performed. The following elements present many overloads.

Overloaded Elements

From Number-Name		To Number-Name		Circuit	Xfrmr	Violations	Max %
43139	DAYTON	43137	DAYTON	1	Yes	122	141.70
40899	ROSS	41161	WOODLAND	1	No	17	125.89
40671	LONGVIEW	40669	LONGVIEW	1	Yes	13	117.56
43541	ST MARYS	43599	TROJAN 1	1	No	7	110.03

The Dayton 115 to 59kV transformer is the most overloaded element. This element had a 95% loading for the base case condition. From the near 4000 single and common mode contingencies, the element presented overloads in 122 contingencies. The violations appeared for several single line contingencies at the 59kV level. This element is excessively loaded. A potential solution is to redirect the low voltage additional flow by creating additional circuits at the high voltage level. Since the Allston generation increased the loading of the Dayton transformer in 3%, this violation in the contingency condition is caused by the new generation.

The Allston to Keeler single line outage is the critical single contingency, causing an overload of 18.6% in the Ross to Woodland line. Currently, this contingency has remedial action scheme associated with it. System expansion is needed in order to avoid RAS for the single contingency.

In order to verify robustness of system expansion design, TLR sensitivities of overloaded lines are computed for contingency conditions, with respect to every generator in the system. This enables the discrimination of violations created by the new generation, or bulk power transmission. It also enables the early determination of potential violations when new generation is included in the model. Thus, the TLR computation includes sensitivities with respect to all the new generators in the sequence although generation output is greater than zero only for the new generators up to that state.

As an example of this computation, consider the Allston to Keeler contingency and the Ross to Woodland line. The following table shows the generators with the largest effect in the Ross to Woodland line, for that contingency condition. Several generators with negative sensitivities are listed at the end of the table. These generators would reduce the loading of the line when its generation is increased. We see that generation at Allston, Trojan, Satsop, Paul, Tacoma, and Cowlitz will further worsen the conditions of this line when implemented in future states. The sensitivity for Allston generation is of 0.089, which represents 47 additional MW in this line due to the 520 MW of new generation.

TLR Sensitivities for Ross-Woodland

Contingency: Allston-Keeler

Number	Name	ID	P Sensitivity	Gen MW	Number	Name	ID	P Sensitivity	Gen MW
45287	SWIFT	1	0.574	300.0	40821	PAUL	1	0.046	0.0
40309	COWL CCP	1	0.135	100.0	45041	CENTR G2	1	0.046	692.0
40671	LONGVIEW	1	0.108	567.0	45039	CENTR G1	1	0.046	692.0
40043	ALLSTON	1	0.089	520.0	41053	TACOMA N	1	0.040	0.0
43017	BEAVER	1	0.089	360.0	41301	XFREDRK	1	0.037	160.0
43019	BEAVER	1	0.089	135.0	41300	XFREDRK	1	0.037	90.0
47260	WAUNA	1	0.087	27.0	42711	ELECTRON	1	0.037	12.0
46623	MAYFIELD	1	0.076	40.0	46671	ALDER11	1	0.036	25.0
47047	GLENOMA	1	0.076	30.0	46615	CUSHMN2	1	0.036	10.0
40307	COWFALLS	1	0.076	17.0	46672	ALDER12	1	0.036	12.0
40199	CENTRALA	1	0.076	10.0	46732	LAGRND	1	0.036	24.0
46627	MOSSY RK	1	0.076	150.0	46613	CUSHMN1	1	0.036	8.0
43599	TROJAN 1	1	0.069	0.0	46733	LAGRND5	1	0.036	41.0
41802	CHEH G2	1	0.051	195.0	46607	COWLITZ	1	0.036	0.0
41803	CHEH ST	1	0.051	230.0	40135	BONNVIL1	1	-0.063	155
41801	CHEH G1	1	0.051	195.0	47216	RVR RD C	1	-0.076	240
40007	ABERDEEN	1	0.049	11.0	45351	YALE	1	-0.089	130
40841	PORT ANG	1	0.048	28.6	45199	MERWIN	1	-0.089	20
40947	SATSOP	2	0.047	0.0	40033	ALCOA	1	-0.105	0
40947	SATSOP	1	0.047	0.0					

The high sensitivity of Allston generation confirms the contribution of the new generation to this overload.

The Longview 230 to 115kV transformer presents a 17% overload with an outage of the Lexington to Longview line or the outage of the Lexington transformer. These violations appear due to the increased flow in the Allston to Longview to Lexington to Woodland to Ross corridor. This points towards system expansion alternatives that decrease the base flow in this corridor.

The Allston to Keeler outage creates several overloads shown in Figure 1.b.

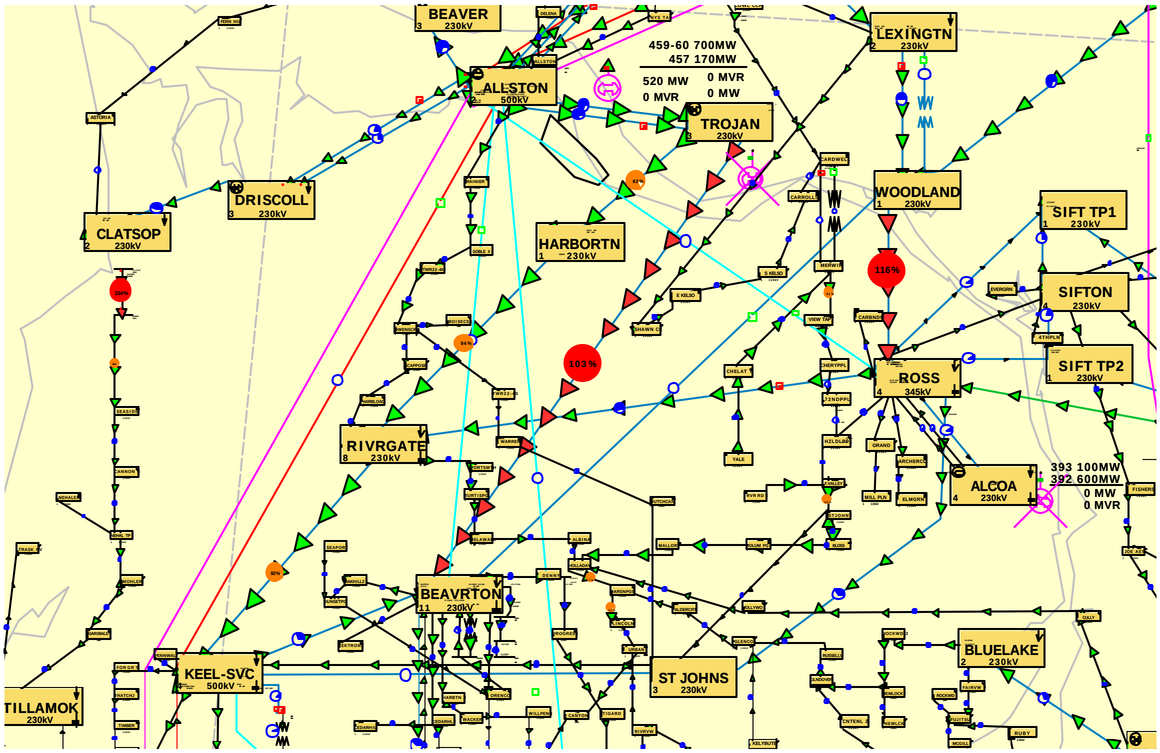

Figure 1.b: Allston to Keeler Contingency without expansion

6.1.3 Proposed System Expansion

Proposed system expansion includes the upgrade of the Dayton transformer from 50 to 60MVA. Further upgrade may be needed for future states. The location of Allston generation makes it difficult to find a way not to affect the flows in the 230 and 115kV systems. An alternative would be to directly connect Allston generation by means of a 500kV to a junction at 2/3 of the Paul to Troutdale line. When this alternative was tested using standard parameters, the flow through the line was close to 1000MW. The limitation of this alternative is that a failure South (1/3) segment of the Paul to Troutdale line would severely overload the Ross to Woodland line.

A second alternative that works better for the Allston generation consists in two new 230kV lines:

a) A 230kV line from Allston to Ross, which bypasses the Ross to Woodland line.

b) A 230kV line from Allston to St. Marys.

This alternative has the property of considerably reducing the flow in the Ross to Woodland line. The following parameters were determined for these lines:

Line Parameters								
From Num-Name		To Num-Name		Ckt	R	X	C	Lim A MVA
40043	ALLSTON	40899	ROSS	1	0.00546	0.05897	0.1232	500.0
40043	ALLSTON	43541	ST MARYS	1	0.00546	0.05897	0.12320	500.0

The incorporation of these new lines resulted in a flow of 334MW in the Allston to St. Marys line and 245MW in the Allston to Ross line. This represents a combined flow close to 580MW. Thus, the lines effectively extract more than the new Allston generation from this area. The flow in the Ross to Woodland line decreased from 377 to 310MW. This is very useful since this line will carry more flow when other generation in the sequence is connected. The St. Marys to Murray line increased from 133 to 217MW. This is not a dangerous effect since the line has a 523MVA rating.

The two new lines do not reduce considerably the number of elements in the 95-100% loading range. However, they achieve a substantial reduction of the severity of the contingencies described in the previous section. The Allston to Keeler single line contingency created the following violations without the new lines, and no violation with the new lines in place.

Violations for Allston to Keeler Line Outage without Expansion								
From Num-Name		To Num-Name		Ckt	Used	Limit	Used %	MVA or Amps?
40899	ROSS	41161	WOODLAND	1	1269.1	1070.1	118.6	Amps
40809	OSTRNDER	40827	PEARL	1	1167.0	1050.0	111.1	Amps
43541	ST MARYS	43599	TROJAN 1	1	1388.6	1315.1	105.6	Amps
40671	LONGVIEW	40669	LONGVIEW	1	294.9	288.0	102.4	MVA

We notice that the redistribution of flows to Murray makes the Dayton transformer increase its loading in 2% up to 99% (considering 50MVA rating). Thus, the upgrade of this element to 60MVA is necessary.

The Longview transformer presents a high sensitivity for Allston generation under an outage of the Lexington transformer. Thus, the Longview transformer requires an upgrade from the 288 to the 350MVA at this state. This expansion will be robust enough to withstand additional I-5 generation.

Figure 1.c shows the final system condition with the described system expansion and the Allston to Keeler contingency.

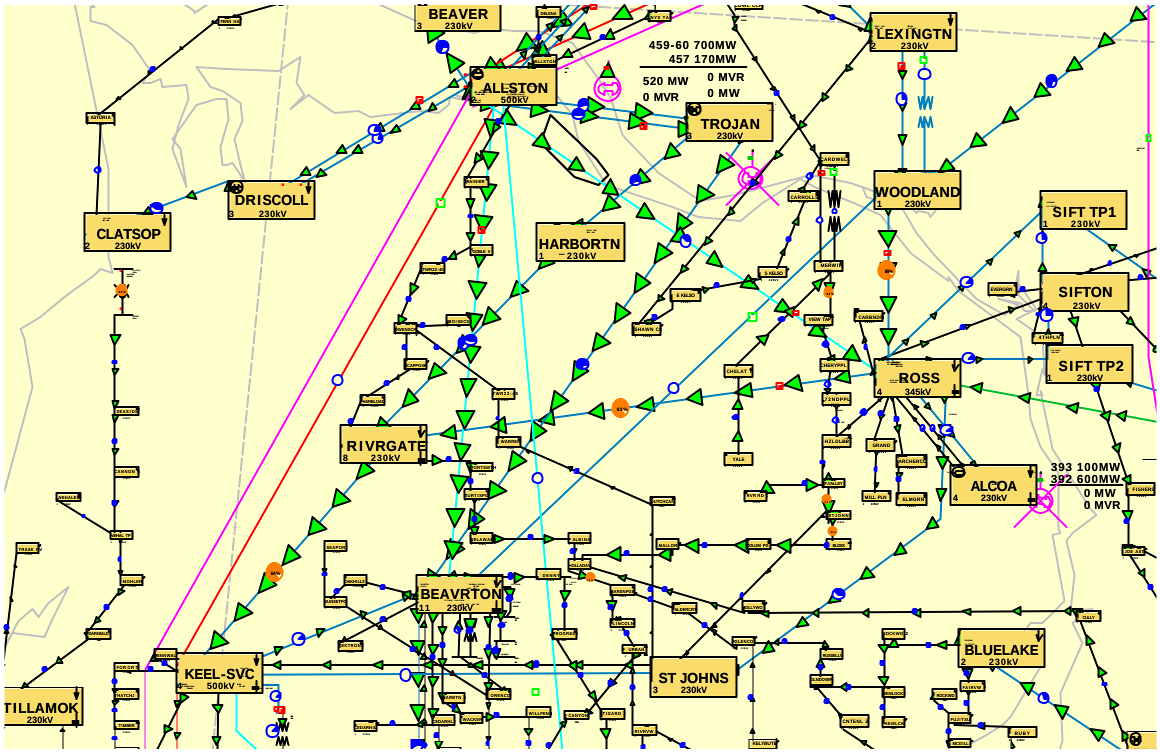

Figure 1.c: Allston to Keeler Contingency with Expansion

6.2 System State 2: Paul Generation (300MW) Request 354, 356, 358, 359

6.2.1 Base Case Results

State 2 includes 520MW of new generation at Allston and 300MW at Paul. The new 230kV Allston to Ross and Allston to St. Marys lines due to Allston generation are assumed to be in place. It is assumed that Paul generation is connected directly to the 500kV bus. The generation (at every state) is modeled with zero reactive power for the base case and for contingency conditions. This is necessary to account for the worst-case condition regarding voltage regulation.

Generation was displaced at Coyote S1 and G1 and 100MW at Herm S. No phase-shifter adjustment for the Custer to Ingledow corridor flow was required.

The base case did not present new violations with Paul generation. Figure 2.a shows the distribution of flows based on PTDF's for a Paul to Coyote transfer.

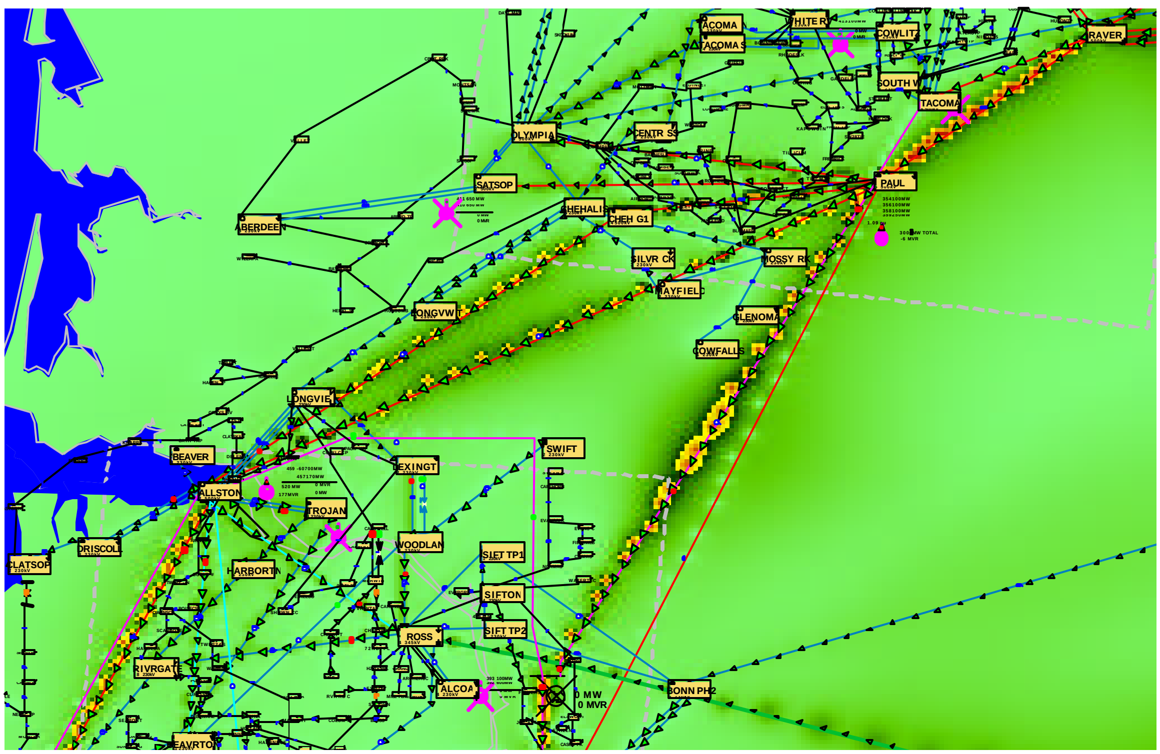

Figure 2.a: PTDF Contouring for a Paul to Coyote Transfer

The figure shows that approximately 30% of the transfer goes to the North path through the Raver to Paul 500kV line. Consequently, Paul generation reduces the flow by the netting effect and this effect is addressed in the simulation. The rest of the flow follows the 500kV paths Paul to Chehalis, Paul to Allston and Paul to Troutdale. Some of the flow gets into the 230 and 115kV level and thus these systems will be affected.

6.2.2 Contingency Analysis Results

The following table lists the most severe contingencies in the I5 corridor for state 2. The list includes both single and common mode contingencies.

Severe Contingencies		
Contingency Label	Violations	Max Line %
L/D CUSTER-INGLEDOW 1&2	40	419.1
L/D CUSTER-MONROE 1&2 (N/S FLOW)	19	166.5
L/D CUSTER-MONROE 1&2 (S-N FLOW)	19	166.5
B/D TROUTDAL 230 BF3, W BUS,LINN LINE	9	136.9
B/D TROUTDAL 230 BF2, W BUS	9	136.4
L/D ALV-MAR & LANE-MAR 500	8	138.0
B/D BONNVILE 230 BFR 1 - ROSS #1 LINE	7	174.4
B/D TROUTDAL 230 BF4, W BUS, GRES LINE	7	134.2
B/D LONGVIEW 115 BF	5	123.5
B/D BONNVILE 230 BFR 2 - ROSS #2 LINE	5	225.6
L40045ALLSTON-40601KEELERC1	2	104.9

The cross analysis of overloaded elements versus contingencies reveals the following elements in the I-5 corridor to be often violated for contingency conditions.

Severe Violations							
From Number-Name		To Num-Name		Ckt	. Xfrmr	Violations	Max % Cont
40899	ROSS	41161	WOODLAND	1	No	6	108.89
43139	DAYTON	43137	DAYTON	1	Yes	6	115.86
43041	BETHEL T	40939	SANTIAM	1	No	6	118.87
43029	BEAVRTON	43145	DENNY	1	No	5	111.59

The Ross to Woodland line still is the limiting element for several contingencies with the Allston and Paul generation in place. The Allston to Keeler contingency slightly overloads this line. At this state, we test this contingency condition for TLR sensitivities as we did for state 1. Paul generation has TLR sensitivity of 0.035. The new 300MW generation at Paul would represent 11 additional MW in this line, which is enough to cause the overload.

TLR Sensitivities for Ross-Woodland

Contingency: Allston-Keeler

Number	Name	ID	P Sensitivity	Gen MW	Number	Name	ID	P Sensitivity	Gen MW
45287	SWIFT	1	0.579	300	41801	CHEH G1	1	0.039	195
40309	COWL CCP	1	0.118	100	41802	CHEH G2	1	0.039	195
40671	LONGVIEW	1	0.085	567	41803	CHEH ST	1	0.039	230
40043	ALLSTON	1	0.064	520	40007	ABERDEEN	1	0.038	11
43019	BEAVER	1	0.064	135	40841	PORT ANG	1	0.037	28.6
43017	BEAVER	1	0.064	360	40947	SATSOP	2	0.036	0
47260	WAUNA	1	0.063	27	40947	SATSOP	1	0.036	0
46627	MOSSY RK	1	0.059	150	45039	CENTR G1	1	0.035	692
46623	MAYFIELD	1	0.059	40	45041	CENTR G2	1	0.035	692
40199	CENTRALA	1	0.059	10	40821	PAUL	1	0.035	300
47047	GLENOMA	1	0.059	30	45251	POWERDLE	1	-0.033	3
40307	COWFALLS	1	0.059	17	43599	TROJAN 1	1	0.05	0
45287	SWIFT	1	0.579	300	41801	CHEH G1	1	0.039	195
40309	COWL CCP	1	0.118	100	41802	CHEH G2	1	0.039	195
43599	TROJAN 1	1	0.05	0	41803	CHEH ST	1	0.039	230

Figure 2.b shows the outage of the Allston to Keeler line, without Allston generation and with 300MW at Paul.

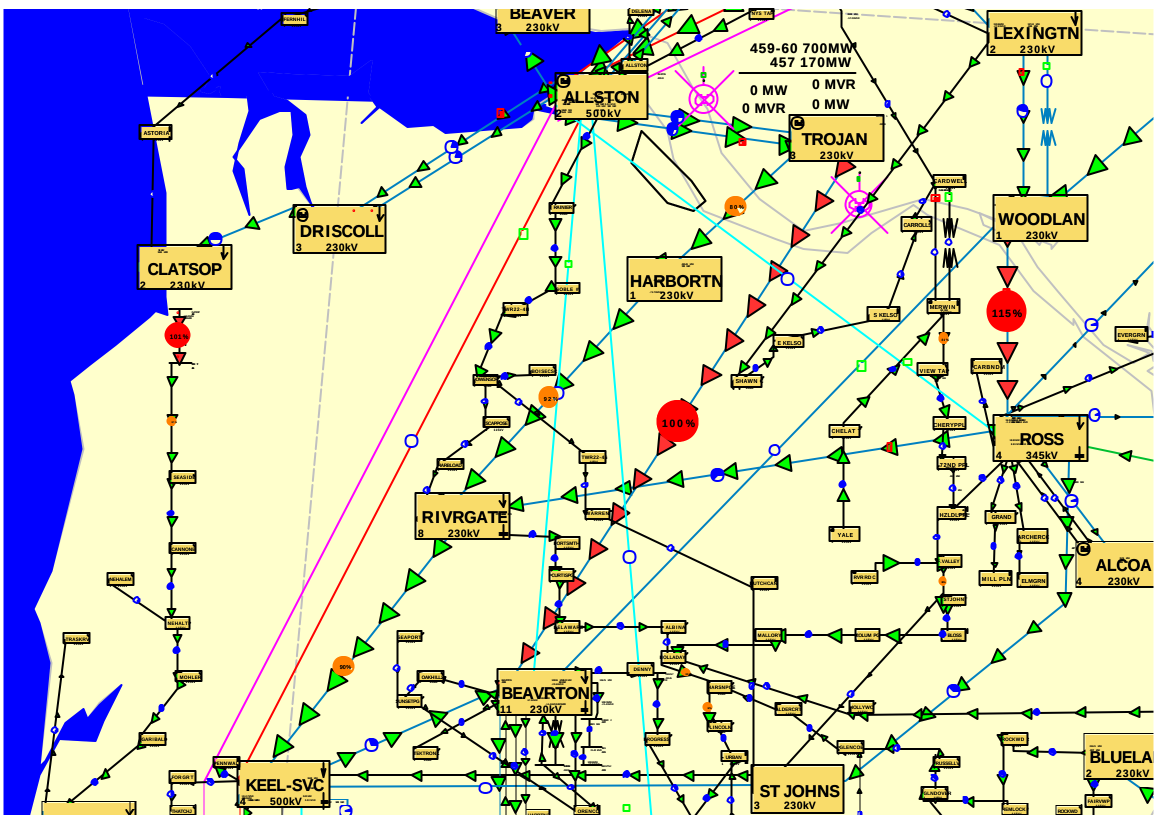

Figure 2.b: Allston to Keeler outage with 300MW at Paul.

Clearly, system expansion is required to solve this condition.

The Dayton transformer presents severe overloads for several contingencies. Single contingencies of Cornelus to Dilley Ckt 1 and Dilley to Scoggin Ckt 1 in the 59kV level produce violations up to 15%.

The Beaverton to Denny 115kV line is overloaded by an outage of the Sherwood transformer. When this outage occurs, the Beaverton to Denny to Progress to Tigard 2 path, being an alternative 115kV link, increases its flow considerably and overloads the mentioned line.

6.2.3 Proposed System Expansion

The Ross to Woodland line is the limiting element. It presents several violations under 10%. This indicates that further reduction of flow by means of system expansion is needed. This could be achieved by creating a parallel circuit with lower impedance. It is convenient to consider a smaller reactance for the Ross to Woodland 230kV line. We assume the following parameters: per unit resistance close to 0.005, per unit reactance equal to 0.05 and capacitance near 0.12 p.u. The rating of the line is assumed equal to 500MVA. This upgrade reduces the Beaverton to Denny overload.

We complement the system expansion with an upgrade of the Dayton transformer to the 75MVA level.

Figure 2.c shows the system with the described expansion, 520MW at Allston and 300MW at Paul, for the Allston to Keeler contingency.

The alternative of creating a bus at 2/3 of the Paul to Troutdale line instead of two new 230kV lines creates an overload of 5% in the Ross to Woodland line for an outage of the South segment of the Paul to Troutdale line. Upgrade of the Ross to Woodland line would be required. This upgrade however tends to drive too much flow to the Ross substation and creates additional overloads in the area. This condition is shown in Figure 2.d. This alternative is discarded in this study.

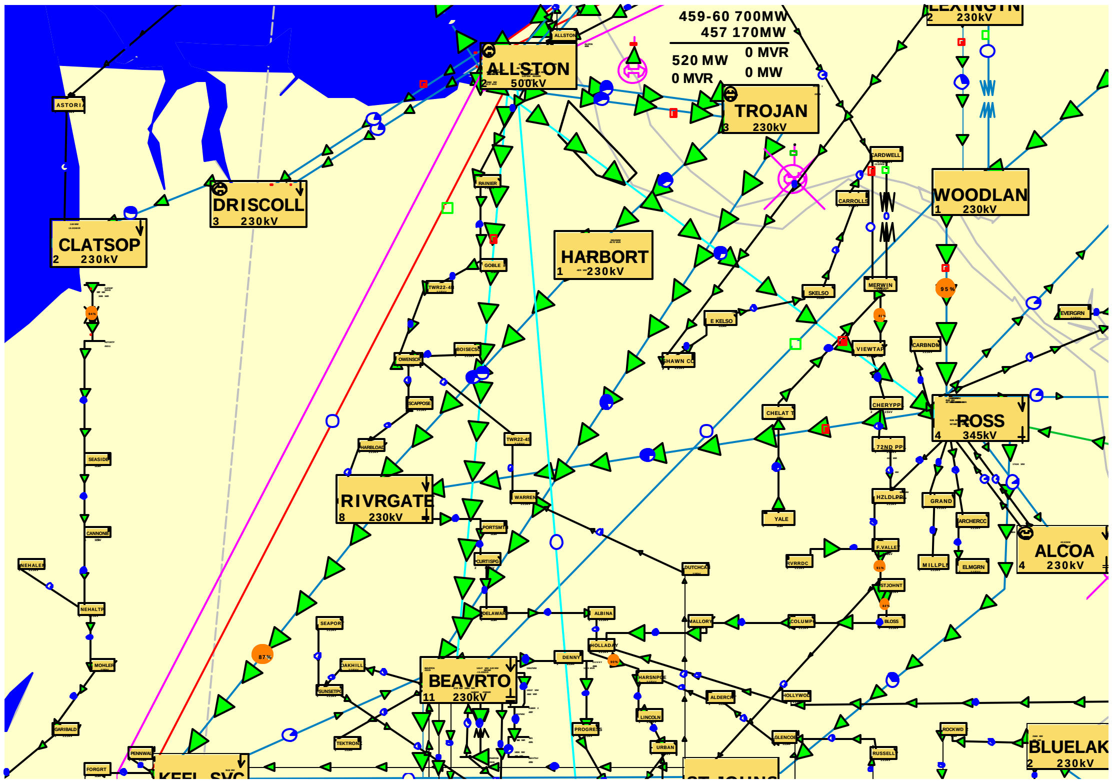

Figure 2.c: Allston to Keeler outage with Paul, Allston and the Expansion

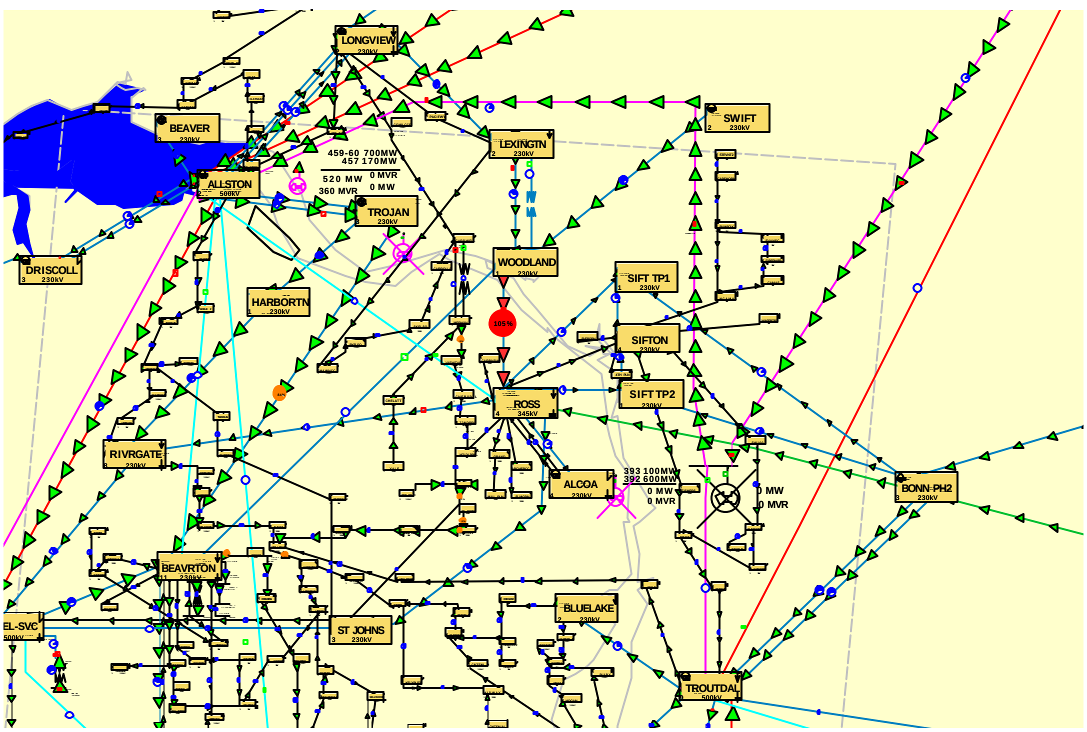

Figure 2.d: Paul-Troutdale segment outage with Allston connected at Junction

6.3 System State 3: Custer Generation (600MW) Request 366, 367

6.3.1 Base Case Results

This state includes the new generation at Allston, Paul, and 600 additional MW at Custer, as well as the system expansion derived from the Allston and Paul generation requirements. The generator at Custer is modeled as directly connected to the 500kV Custer W bus (with zero reactive power). The generation is balanced by displacements at Herm G and Rath G2. Phase shifter controls for the Ingledow to Custer flow level remains the same.

The base case presented no new violations. The elements in the 90-100% loading range are almost the same as in the previous case. Figure 3.a shows PTDF contouring for a transfer from Custer to Herm G and Rath G2.

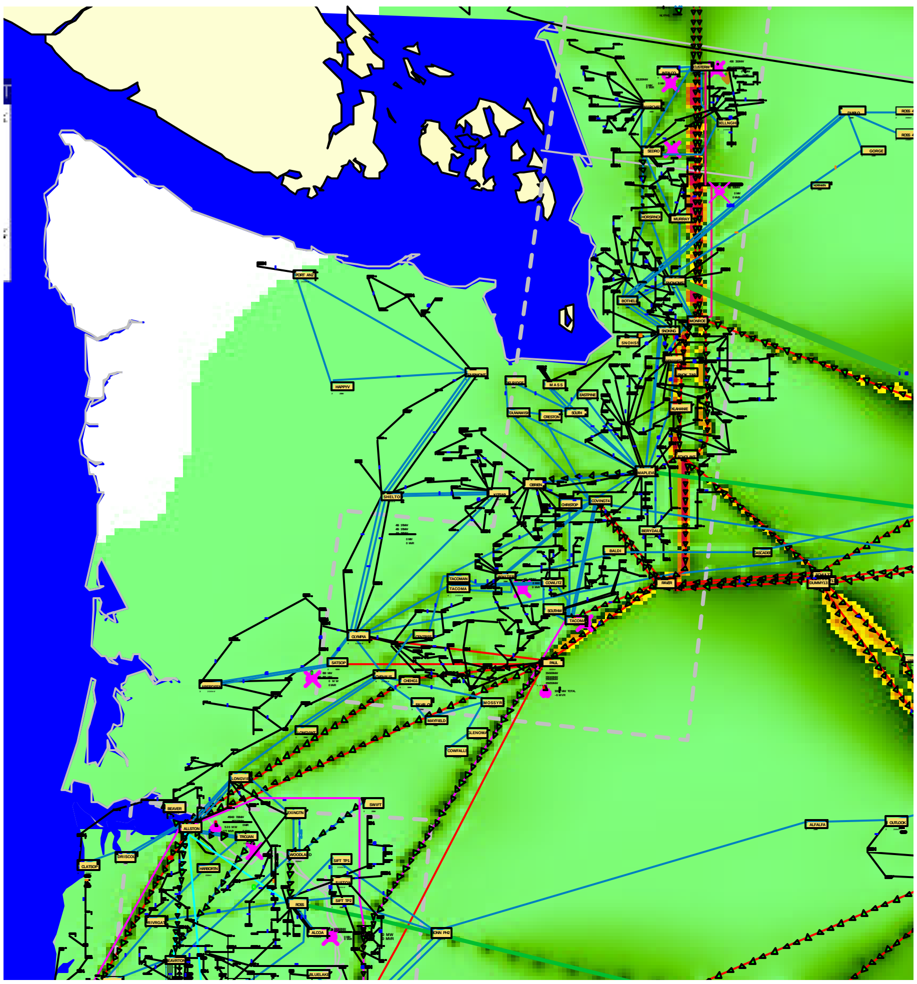

Figure 3.a: PTDF Contouring for a Custer Transfer to Herm G and Rath G2

The figure shows that around 20% of the flow reaches Allston either from Paul or from Chehalis. Around 10% follows the path Allston to Keeler to Pearl. These lines will be loaded approximately in 60 additional MW. The Raver to Paul line has 17% PTDF.

Figure 3.b shows a close-up of the contouring in the Custer/Monroe area. Part of the flow (approximately 20%) takes the 230kV system following (Bellingham) Sedro to Horse Ranch to Snohomish, whereas the rest of the flow takes the 500kV system. Since the state sequence includes several requests in the Custer area, the flow in these elements will considerably increase in the future states. System expansion in this area will be needed to address these problems.

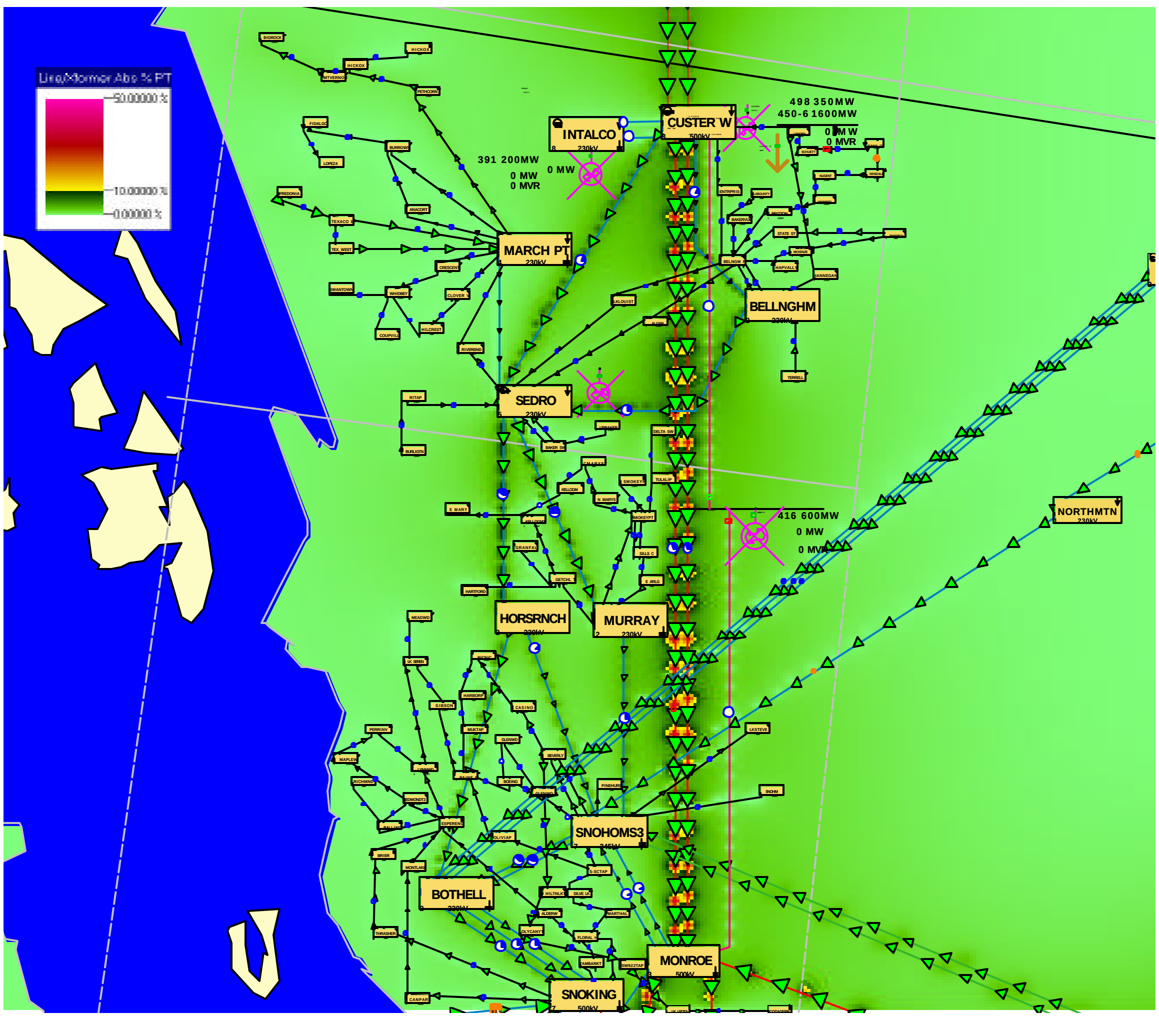

Figure 3.b: Close up of PDTF Contouring for Custer Generation

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6.3.2 Contingency Analysis Results

The following is the list of the severe contingencies for state 3.

Severe Contingencies		
Contingency Label	Violations	Max Line %
L/D CUSTER-INGLEDOW 1&2	38	418.8
L/D CUSTER-MONROE 1&2 (N/S FLOW)	28	210.1
L/D CUSTER-MONROE 1&2 (S-N FLOW)	28	210.1
B/D TROUTDAL 230 BF2, W BUS	12	136.4
B/D TROUTDAL 230 BF3, W BUS,LINN LINE	12	136.9
L/D ALV-MAR & LANE-MAR 500	10	138.5
B/D TROUTDAL 230 BF4, W BUS, GRES LINE	10	134.8
B/D BONNVILE 230 BFR 1 - ROSS #1 LINE	8	174.3
L/D MARION-ALV & MARION-SANT 500	6	123.6
B/D BONNVILE 230 BFR 2 - ROSS #2 LINE	6	225.6
BF 5117 RAVER-ECHO L-MAPLE V	6	115.6
B/D LONGVIEW 115 BF	6	123.6
L/D KEELER-PRL 500 & SHER-CARL 230	4	102.9
BF 5084 MARION-ALVEY-DIXONVLE	4	104.5
BF 4283 KEELER-PEARL-OSTRNDER	4	120.6
L/D RAVER-PAUL 500 & S TAC-CHEH 230	4	138.0
L/D ALLST-TROJ2,ALLST-KEEL 500	4	104.7
BF 4448 HANFORD-OSTRANDER-TROUTDAL	4	103.7
L/D RAVER-PAUL 500 & COUL-OLY 300	4	133.6
L/D ALLST-TROJ1,ALLST-KEEL 500	4	105.0
L/D KEEL-PRL 500,CASCADTP-SHERW	4	102.9
L/D ALLST-KEEL 500,ALLST-DRISCOLT	3	104.0
L40045ALLSTON-40601KEELERC1	3	104.0
L/D RAV-COV & RAV-PAUL 500	3	119.3
L40821PAUL-40869RAVERC1	3	121.7
BF 4532 RAVER-PAUL-CENTR G2	3	135.7
L/D OSTRANDER-TROUTDALE 500	3	104.4
B/D BONNVILE 230 BFR 3 - BUS	3	113.7

The contingency analysis reveals an increased number and severity of the overloads created by the common mode contingencies involving the Custer to Monroe circuits. Other common mode contingencies in this area create additional violations as well. If RAS up to the 2900MW level is not able to solve violation conditions, then system expansion must be designed.

The cross analysis for violating elements reveals the following as the elements that become overloaded for more than two contingencies.

Severe Violations							
From Number	From Name	To Number	To Name	Circuit	Xfrmr	Violations	Max %
43029	BEAVRTON	43145	DENNY	1	No	7	112.58
43041	BETHEL T	40939	SANTIAM	1	No	5	118.47
40043	ALLSTON	43541	ST MARYS	1	No	5	103.91

The Beaverton to Denny 115kV line presents a 1% overload for the Ostrander to Troutdale 500kV single line outage. This is not a severe overload. Higher overloads are caused by common mode contingencies.

The Bethel to Santiam line presents a 4% overload for the McLoughlin to Monitor outage. Higher overloads appear for common mode contingencies.

The new Allston to St. Marys 230kV lines included as system expansion for states 1 and 2 presents a slight overload with the Allston to Keeler single outage line. This new line was modeled with a 500MVA rating. A 600MVA rating is needed and assumed in this line for future states. Exact parameters of the line would be determined in a System Facilities Study for Allston and Paul generation.

The severe contingency table suggests that the single most severe contingency is the Raver to Paul 500kV line. The White River to Fernhill 57.5kV line is overloaded in 21% with Paul generation and 29% without Paul generation. This occurs since this line is a weak parallel path for the Raver to Paul flow. Custer generation only contributes to 4% of this overload. This problem can be mitigated with RAS. The following are TLR sensitivities that could be used to mitigate this overload.

TLR Sensitivities White River to Fernhill				
Contingency: Raver to Paul				
Number	Name	ID	P Sensitivity	Gen MW
42733	WRGEN3-4	1	0.008	25
42731	WRGEN1-2	1	0.008	25
45041	CENTR G2	1	-0.006	692
45039	CENTR G1	1	-0.006	692
41803	CHEH ST	1	-0.006	230
41802	CHEH G2	1	-0.006	195
41801	CHEH G1	1	-0.006	195
40821	PAUL	1	-0.006	300
40947	SATSOP	2	-0.007	0
40947	SATSOP	1	-0.007	0
40007	ABERDEEN	1	-0.008	11
40841	PORT ANG	1	-0.009	28.6

The Allston to Keeler Contingency has the effect of bringing the lines in the Woodland to Ross to Rivergate to Keeler close to overload. As the PTDF's for injection at Custer are positive in these lines, further generation at Custer would require system expansion in the Portland area. The Allston to Keeler outage does not create further violations with or without Allston and Paul generation. This suggests that the system expansion for the previous state is not robust enough to handle the removal of netting effects from some existing generation, like the River Road plant. It is assumed that RAS will mitigate this problem.

6.3.3 Proposed System Expansion

Based on the contingency analysis results, system expansion for the 600MW generation level at Custer is limited to RAS.

6.4 System State 4: Custer Generation (600MW) Request 391

6.4.1 Base Case Results

The base case for this state includes generation at Allston (520MW), Paul (300MW) and Custer (1200MW). Generation displacement for the additional 600MW at Custer was implemented at RathGen and Libby (470MW). The phase shifter for the Ingledow to Custer flow was set up at 5 degrees. There were no violations in the base case. The flow distribution was the same as the one determined for state 3.

6.4.2 Contingency Analysis

The following were determined as the single contingencies that created overloads in the I-5 corridor:

Severe Contingencies

Contingency Label	Skip	Processed	Solved	Violations	Max Line %
L46431GORGE-45735NORTHMTNC1	NO	YES	YES	3	114.4
L45735NORTHMTN-41327SNOHS1C1	NO	YES	YES	3	112.9
L40899ROSS-41021STJOHNSC1	NO	YES	YES	1	104.6
X41021STJOHNS-41019STJOHNSC1	NO	YES	YES	1	104.6
X45183LONEPINE-45179LONEPINEC1	NO	YES	YES	1	114.2
L40093BELLNGHM-42067HANNEGANC1	NO	YES	YES	1	109.0
L43039BETHEL-45111FRYC1	NO	YES	YES	1	125.3
X42100SEDRO-42101SEDROC1	NO	YES	YES	1	103.7
L42104MARCHPT-42100SEDROC1	NO	YES	YES	1	102.7
X45167KNOTT-45165KNOTTC1	NO	YES	YES	1	104.2
L42779SUMNER-42701WHITERVC1	NO	YES	YES	1	104.4
L40099BENTON-40735MIDWAYBC1	NO	YES	YES	1	103.0
X42300SAMMAMSH-42301SAMMAMSHC1	NO	YES	YES	1	129.9
L40045ALLSTON-40601KEELERC1	NO	YES	YES	1	102.2
X40599KEELER-40597KEELERC2	NO	YES	YES	1	109.5
L45181LONEPINE-45271SAGEROADC1	NO	YES	YES	1	127.6
X42300SAMMAMSH-42301SAMMAMSHC2	NO	YES	YES	1	130.1
L40821PAUL-40869RAVERC1	NO	YES	YES	1	127.1
L45183LONEPINE-45195MERIDINPC2	NO	YES	YES	1	125.5
L42108BAKERSW-42101SEDROC2	NO	YES	YES	1	130.7
L45165KNOTT-43297LONEFIR2C1	NO	YES	YES	1	102.4

The previous table shows that for this state the new generation at Custer makes the overall I-5 corridor system handle more North to South flow. Most of the violations are due to bulk power transmission for the conditions assumed in this state. Figure 4.a shows the base case with 1200MW at Custer and Figure 4.b shows the Custer to Monroe single line outage in the same geographical area.

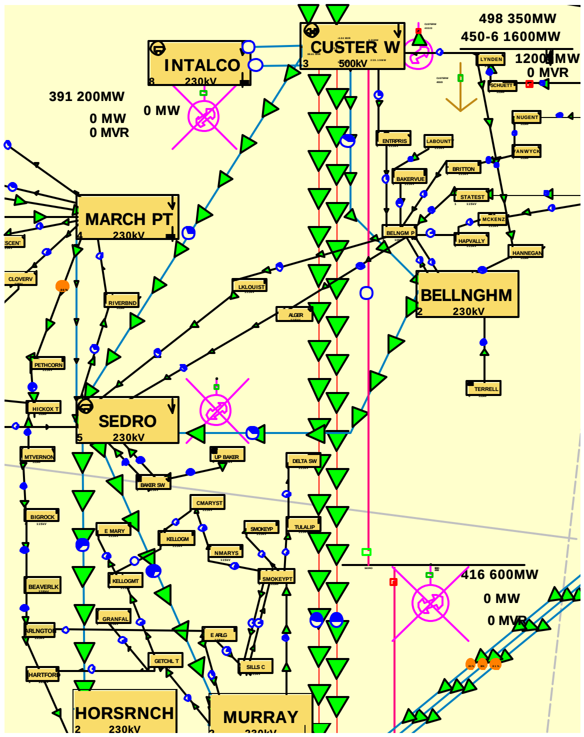


Figure 4.a: Base Case Flow

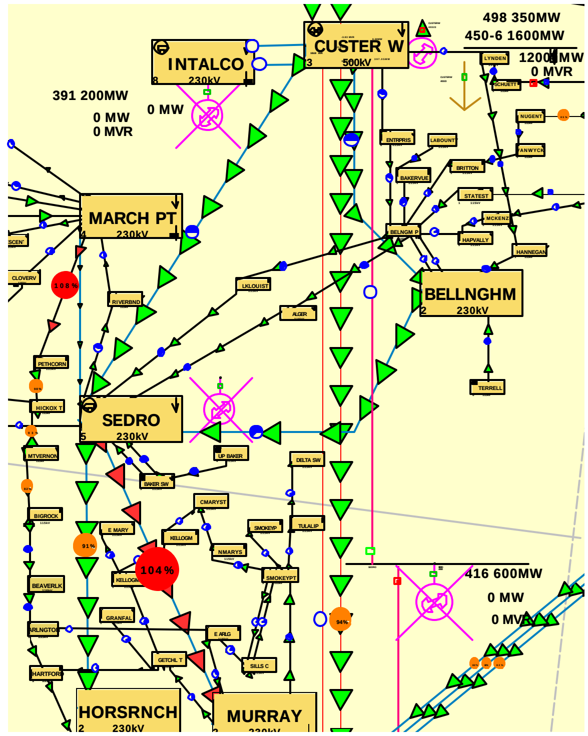


Figure 4.b: Custer to Monroe Outage

A sample overload due to Custer generation is the March PT to Pethcorn 115kv line for an outage of one of the Custer to Monroe 500kV lines. The TLR generator sensitivities are shown in the following table.

TLR Sensitivities for March TP to Pethcorn

Contingency: Custer to Monroe, Ckt 1

Number	Name	ID	P Sensitivity	Gen MW	Number	Name	ID	P Sensitivity	Gen MW
42134	MRPTGENL	1	0.123	23	42021	SUMAS 1	1	0.030	83
42132	MRPTGEN2	1	0.123	37	42022	SUMAS L	1	0.030	48
42131	MRPTGEN1	1	0.123	37	42033	TENASKAL	1	0.029	80
42133	MRPTGEN3	1	0.123	37	42031	TENASKA1	1	0.029	82
42112	FREDONA2	1	0.103	100	42032	TENASKA2	1	0.029	82
42111	FREDONA1	1	0.103	100	42042	WHITHRN2	1	0.027	74.4
42124	UP BAKER	1	0.062	81	42043	WHITHRN3	1	0.027	74.4
42121	LO BAKER	1	0.062	59.5	40573	INTALCO	1	0.020	0
42100	SEDRO	1	0.035	0	51089	V.I.T.	1	0.016	0
42012	ENSERCH2	1	0.033	37	51053	BRIDGE2	1	0.016	300
42014	ENSERCHL	1	0.033	41	40323	CUSTER W	1	0.016	1200
42013	ENSERCH3	1	0.033	37	45850	KIMCLK L	1	-0.014	45
42011	ENSERCH1	1	0.033	37	45689	JACKSN2	1	-0.017	40

This shows that even though the sensitivity for Custer W generation is not large, the 1200 MW level at this bus creates some 18 additional MW, enough to overload this line in contingency conditions. We note that the new Sedro generation, modeled, but not connected for this state has a considerably higher sensitivity.

6.4.3 Proposed System Expansion

One of the goals of system expansion for Custer generation is to avoid that the additional flow increase the loading in the 230 and 115kV system in the Seattle area for contingency conditions. System expansion in the low voltage system is difficult due to the level of interconnection of elements in these areas. A strategy to avoid this effect in the low voltage system is to design high voltage expansion that would carry a similar amount of flow than the one that would be distributed in the low voltage system for the contingency condition. In other words, if 1200MW of Custer generation were in place, then the system expansion lines would carry approximately that amount of flow in the base case. This would leave the low voltage system in similar conditions as before. However, it is necessary to verify that outages of the proposed new lines with the new generation in place do not send too much flow back to the low voltage lines.

Figure 3.a, 3.b and the contingency results show that the lines in the Portland and Seattle areas carry considerably more flow for states 3 and 4. A partial expansion alternative is to incorporate series capacitors in 500kV elements located to the East region of the system in order to attract some of the flow towards that region. Convenient locations to implement series capacitors are the Schultz to Vantage and Vantage to Handford 500kV lines. Standard values of series capacitors connected to these lines reduced the corresponding reactance to 50%. These series capacitors could be a mechanism to mitigate overloads and reduce the flow in the Portland area. The power flow simulation for the base case with the series capacitors resulted in some high voltage problems. The following table compares relevant flow values in the system with and without series capacitors. The Raver to Paul 500kV line represents the major link to the flow into the Portland area. We see that the series capacitors would reduce the flow into this area in at least 665 MW. The PTDF of the Paul to Raver line for the Custer to Herm S transfer is roughly 20%. This means that approximately 3000MW would be needed at

Custer in order to drive the Portland area to a similar loading condition as the one in the base case without the series capacitors.

Sample Flow Values		
Element	Without SC MW	With SC. MW
Raver to Paul	1391	724
Schultz to Vantage	1115	4194
Echolake to Raver	1596	1580
Allston to Keeler	1533	1205
Troutdale to Ostrander	513	234

However, contingency conditions are more restrictive and we cannot claim the use of the capacitors would be enough for this state. Furthermore, this expansion has two limitations:

a) The expansion does not contribute to relieve the extra loading in the parallel 230kV system around the Horse Ranch/Bothell area. The additional flow for 1200MW at Custer equal 120MW through these elements. For example, the Sedro to Horse Ranch 230kV line outage overloads the Sedro to Murray 230kV line for this condition. The system expansion must relieve overloads North of Echolake

b) Other lines in the Vantage area may be heavily loaded.

The severe overloads in the Seattle area require the reinforcement of the circuits out of Custer to the South for the 1200MW level. A convenient expansion alternative is a third Custer to Monroe 500kV circuit. RAS will still be necessary with this line for few contingencies.

We recall that the conditions in the Portland area may be worsened in the Tacoma area if Allston and Paul generation are not included, but the Custer generation is. For example, without these two sources the Raver to Paul outage creates the following violations:

Violations for the Paul-Raver Contingency								
From Number	From Name	To Number	To Name	Circuit	Used	Limit	Used %	MVA-Amps
42727	FERNHILL	42702	WHITE RV	1	301.4	200.8	150.1	Amps
42758	GARDELLA	42701	WHITE RV	1	573.5	552.2	103.8	Amps
40793	OLYMPIA	41055	TACOMA S	1	1537.9	1519.9	101.2	Amps
45043	CENTR SS	41053	TACOMA N	1	1077.9	1070.1	100.7	Amps
42508	BERRYDAL	42638	PIPE LK	1	342.9	340.9	100.6	Amps

This condition would require additional system expansion, including a Tacoma to Paul 500kV line. We assume though that this line is not included for this state. We consider these assumptions in order to identify necessary system expansion to handle multiple generation patterns, so reliance on the netting effect is minimized.

Additional overloads in the Portland area are either existing or can be solved by RAS.

6.5 System State 5: Alcoa Generation (700MW) Request 392, 393

6.5.1 Base Case Results

Alcoa Generation was directly connected to the 230kV bus. Corresponding generation displacement included 100MW at Libby, 294MW at Hungry Horse, 95 MW at Dworshak 1 and 2 each, and the rest at Dworshak 3. Phase shifter adjustment for the Ingledow to Custer flow was not required for the base case condition. The base case presented the following violations:

Base Case Violations

From Number	From Name	To Number	To Name	Circuit	Used Flow	Limit	Used % of Limit	MVA-Amps
40033	ALCOA	40899	ROSS	1	1599.3	1199.9	133.3	Amps
43459	RIVRGATE	40899	ROSS	1	1124.5	1070.1	105.1	Amps
45127	HARRISON	45141	HOLLADAY	1	924.7	900.2	102.7	Amps

Figure 5.a shows that the new generation at Alcoa attempts to reach the 500kV bus at Keeler. Thus, part of the flow travels to the West following the path Alcoa to Ross to Rivergate to Keeler and then back East through the path Keeler to Pearl to Ostrander. This causes the new violations as well as a number of lines with increased flow in the Portland area.

In order to mitigate the Ross to Alcoa overload, it is necessary to re-conductor this line to support 700MVA instead of 478. This would result in a 91% loading of the Ross transformer for the base case. However, this would create a severe overload in the transformers when one circuit is outaged. Thus, it is necessary to create a second 230kV circuit Alcoa to Ross, keeping the original parameters and rating of the line.

Alternatively, it is convenient to help the Alcoa generation reach the 500kV system to the East. A new Ross to Troutdale or Alcoa to Troutdale 230kV would be required. A better alternative is to move the Alcoa generation to a S/E located at 2/3 of the Paul to Troutdale 500kV line. The PTDF contouring for a transfer with this alternative is shown in Figure 5.b.

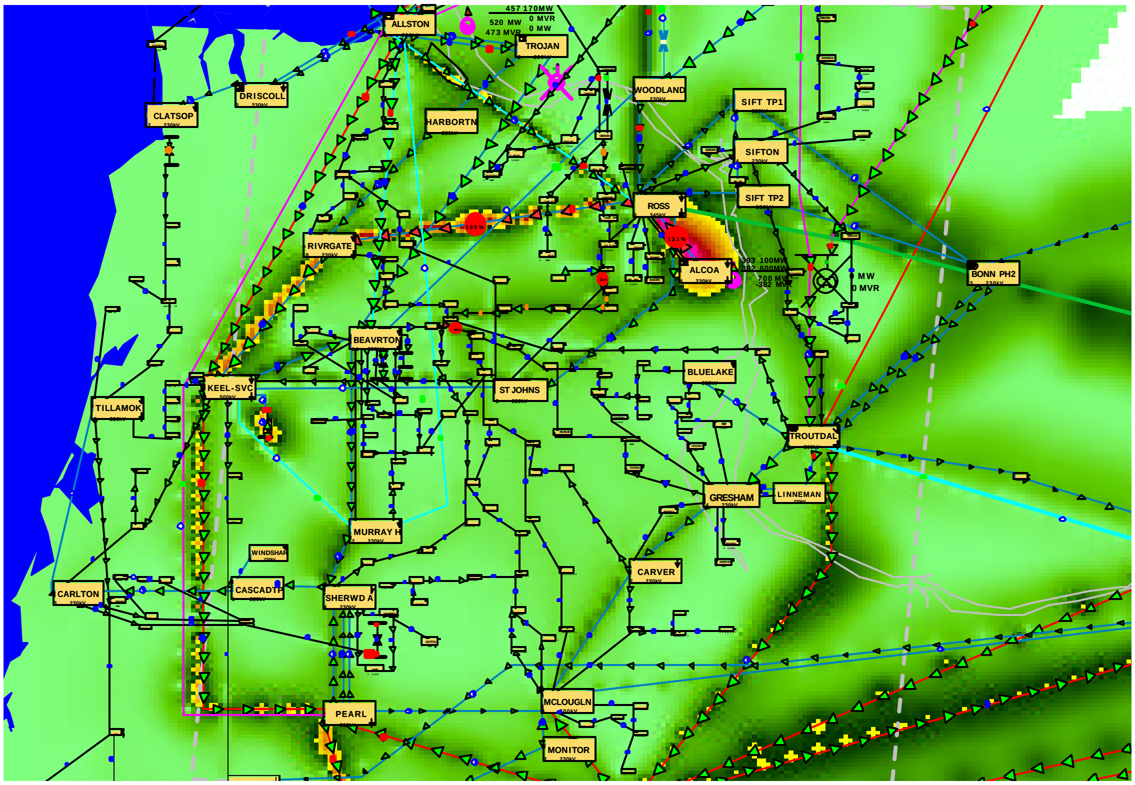


Figure 5.a: PTDF Contouring for Alcoa Generation

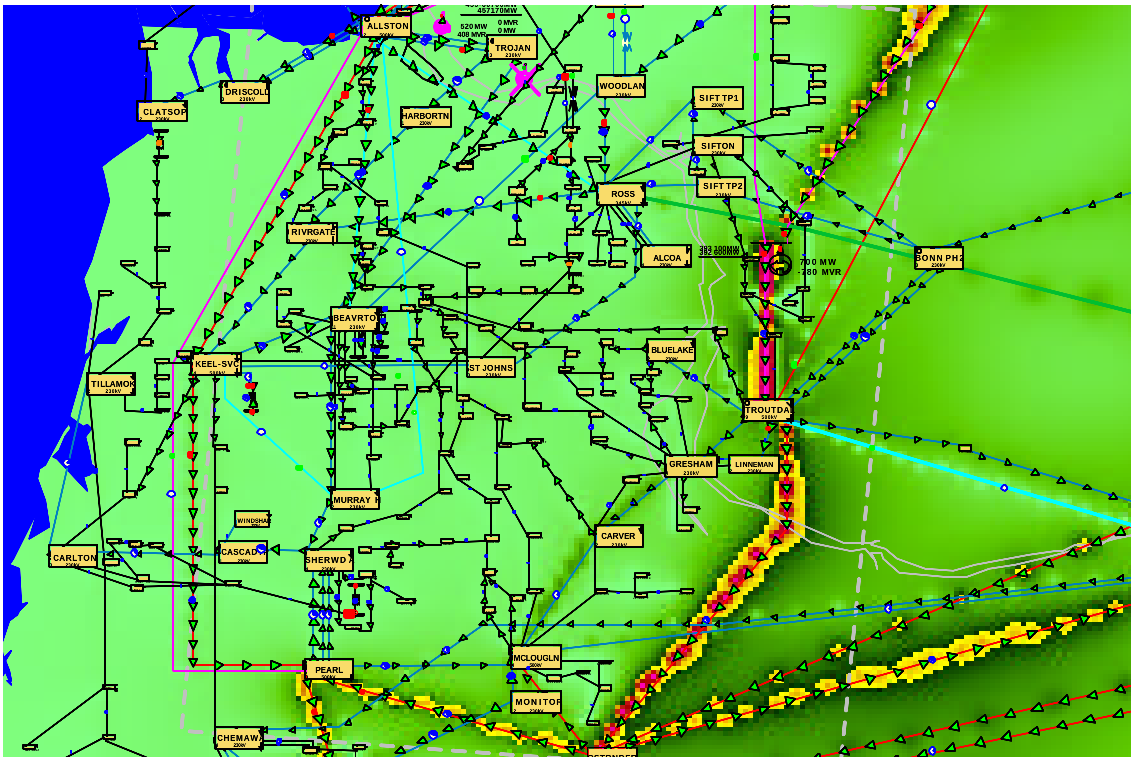


Figure 5.b: PTDF Contouring for Alcoa Generation @ 2/3 of Paul-Troutdale

The connection of Alcoa generation to the 500kV system results in the flow going directly towards the East. Thus, the Alcoa generation does not have much impact in the flows in the Portland area. We proceed with this alternative.

6.5.2 Contingency Analysis

The following table shows a comparison of the Contingency Analysis at state 0 with the corresponding contingency analysis at state 5. Single contingencies are listed.

Number of Violations with Respect to State 0

Decreased Number of Violations	Increased Number of Violation
L40045ALLSTON-40601KEELERC1	L45165KNOTT-43297LONEFIR2C1
L43313MCLOUGLN-43329MONITORC1	L42779SUMNER-42701WHITERVC1
L43041BETHELT-40939SANTIAMC1	L40093BELLNGHM-42067HANNEGANC1
L40051ALVEY -40714DUMMY105C1	L40809OSTRNDER-41095TROUTDALC1
X43021BEAVER-43017BEAVERC1	L40821PAUL -40869RAVERC1
L40699MARION-40941SANTIAMC1	L40899ROSS-41021STJOHNSC1
L40597KEELER-40805ORECITYC1	X43527SHERWOOD-43525SHERWDBC1
L40699MARION-40827PEARLC1	L41093TROUTDAL-45301TROUTPP1C1
L41326SNOHS5-41008SNOKS3C1	X41021STJOHNS-41019STJOHNSC1
L40027ALBANY -40939SANTIAMC1	L45165KNOTT-43297LONEFIR2C1
L43039BETHEL -43329MONITORC1	L42779SUMNER-42701WHITERVC1
X40941SANTIAM-40939SANTIAMC1	L40093BELLNGHM-42067HANNEGANC1
X40821PAUL -45039CENTRG1C1	
X40821PAUL -45041CENTRG2C1	
X43329MONITOR-43327MONITORC1	

The comparison shows that the state 0 presents several violations that are not shown in state 5 and vice-versa. The reduction in the number of violations is due to the system expansion and netting effect of Alcoa. The increase in the number of violations is due to the new Alcoa generation as well as generation at previous states. In general, Alcoa generation tends to reduce the East to West flow in the system.

6.5.3 Proposed System Expansion

System expansion for Alcoa generation consists in a S/E around 2/3 of the Paul to Troutdale 500kV line. Alcoa generation is considered close enough for this to be possible. With this expansion the effect of Alcoa flows are confined to the East of the Paul to Troutdale line and no more overload occurs in the low voltage system. Finally, since the Troutdale transformer has a 47% TLR sensitivity with respect to Alcoa generation for a Troutdale to Ostrander outage, it requires an upgrade to the 1500MVA level.

Figure 5. c show the Bus-View diagram of the Troutdale 41095 500kV bus, which shows an outage of Ostrander to Troutdale.

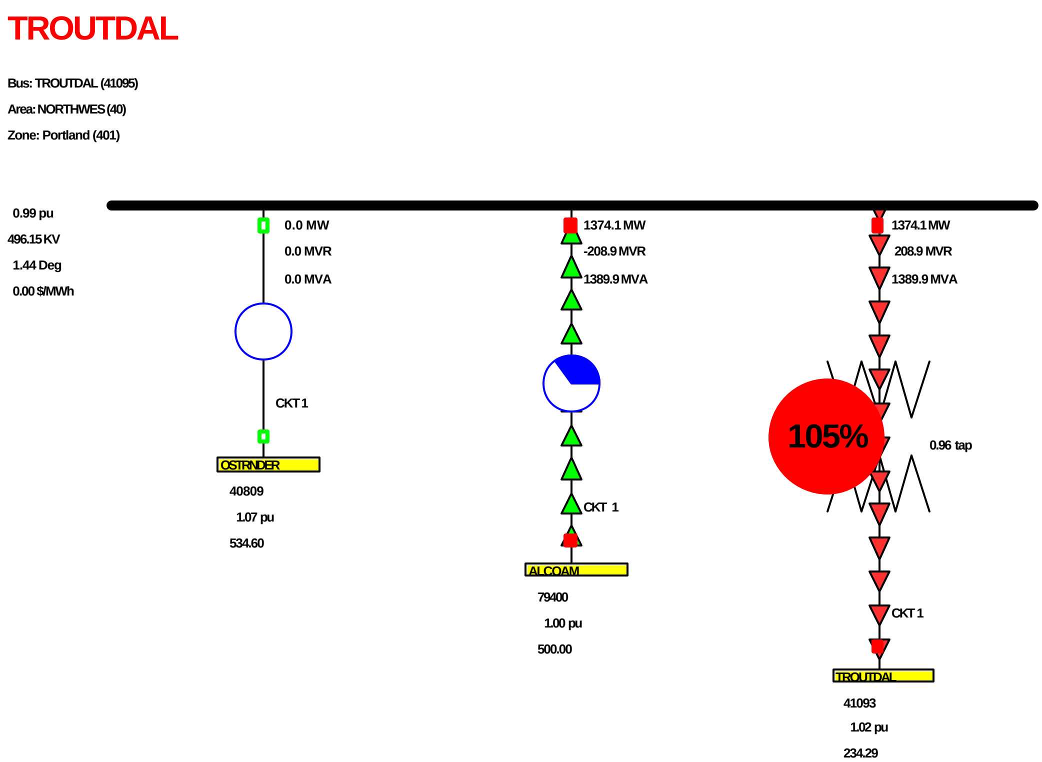


Figure 5.c: Bus View of Troutdale with Ostrander to Troutdale Outage

Thus, this transformer must be upgraded.

6.6 System State 6: Satsop Generation (1300MW) Request 410-411

6.6.1 Base Case Results

Satsop Generation is modeled directly to the 230kV bus. Generation is displaced primarily at Little Goose, Low Grand and Lower Monumental. Phase shifter control for the Ingledow to Custer flow is adjusted to +15 degrees. The following violations occur in the base case:

Base Case Violations

From Number	From Name	To Number	To Name	Circuit	Used Flow	Limit	Used %	MVA-Amps
40277	COSMOPLS	40871	RAYMOND	1	289.8	280.1	103.4	Amps
40793	OLYMPIA	40947	SATSOP	3	640.7	640.1	100.1	Amps

This condition is shown in Figure 6.a.

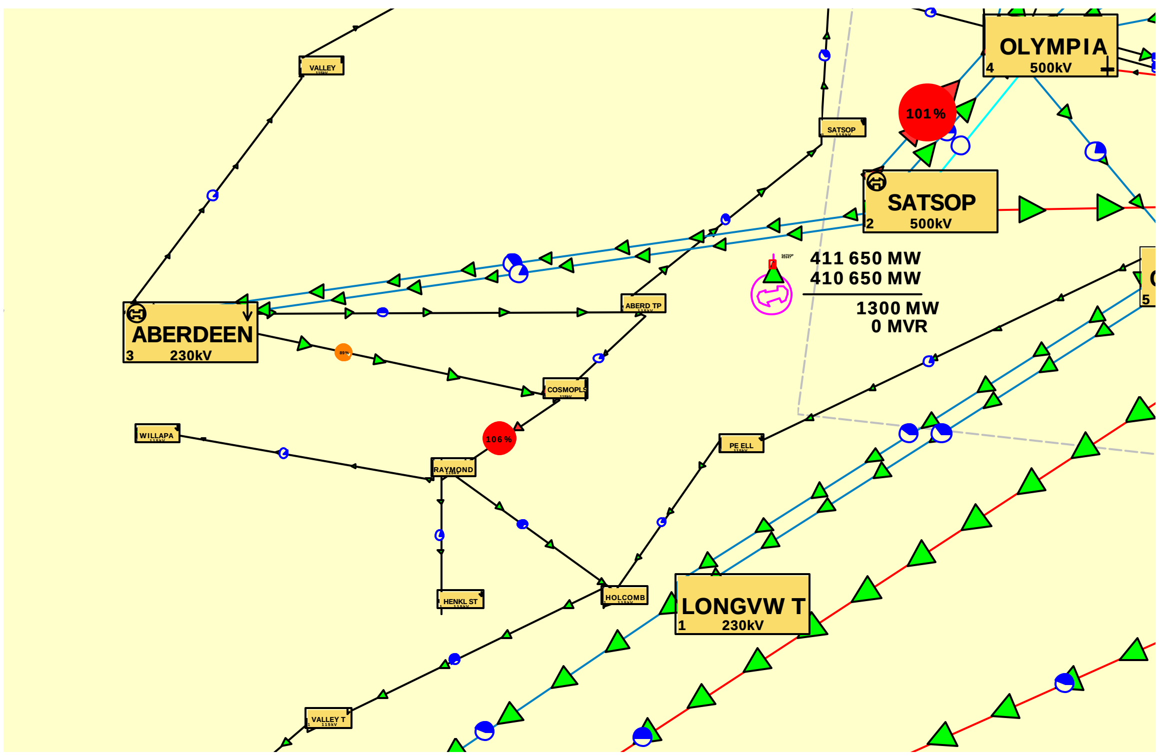


Figure 6.a: Base Case Violations with 1300MW at Satsop

The Cosmopolys to Raymond 115kV line becomes overloaded due to more flow from Satsop to the South following the 115kV path from Aberdeen up to Longview. The Cosmopolys to Raymond overload may be solved by sectionalizing the Holcomb to Valle T 115kV line. This reduces the flow in the circuit in 50MW. Otherwise, contingencies such as the Chehallis to Pe Ell and Pe Ell to Holcomb would severely overload the Cosmopolys to Raymond line

The Olympia to Satsop overload would require a new circuit to reliable extract the generation from Satsop. This circuit was included in the model with the following record. Circuit 3 of this link would also need an upgrade to these values for the Satsop to Paul 500kV line outage.

New Line Parameters								
From Num	Name	To Num	Name	Circuit	R	X	C	Lim A MVA
40793	OLYMPIA	40947	SATSOP	4	0.00528	0.03668	0.07127	426.3

With this base case system expansion, the system conditions are as shown in Figure 6.b.

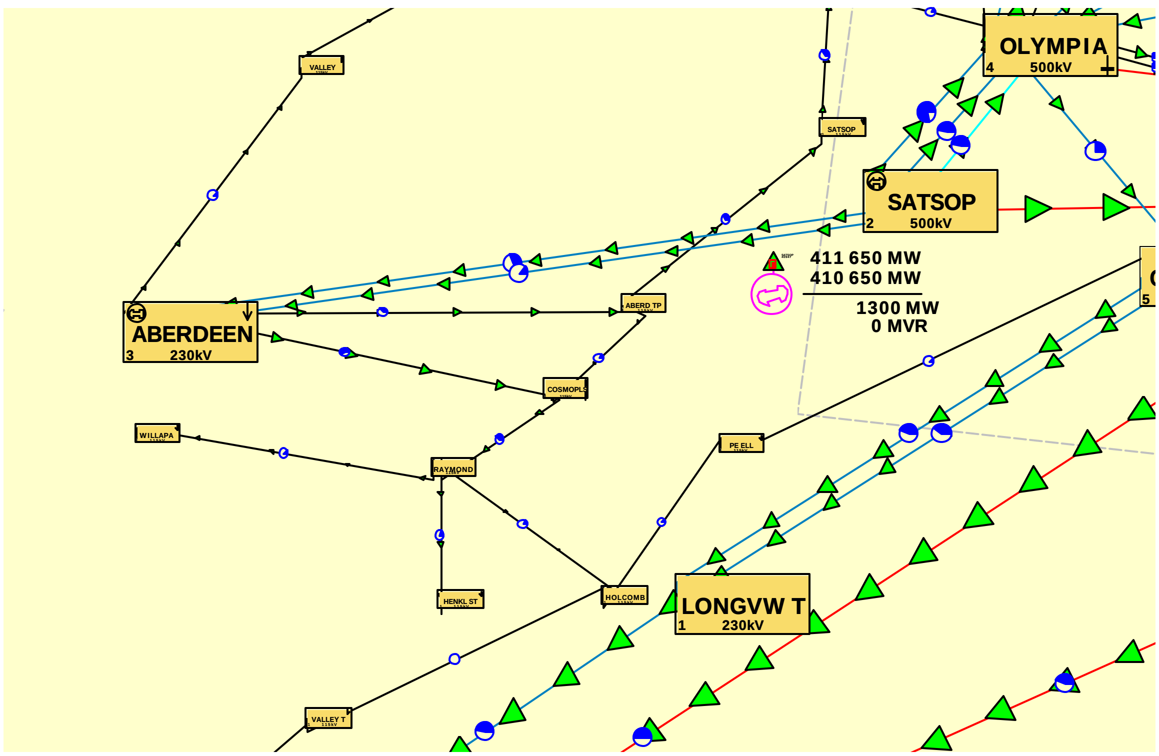


Figure 6.b: Base Case with Expansion

The Figure below shows the PTDF Contouring for Satsop generation. The flow goes primarily through the high voltage system. Around 40% of the flow goes North of Paul and 60% South of Paul.

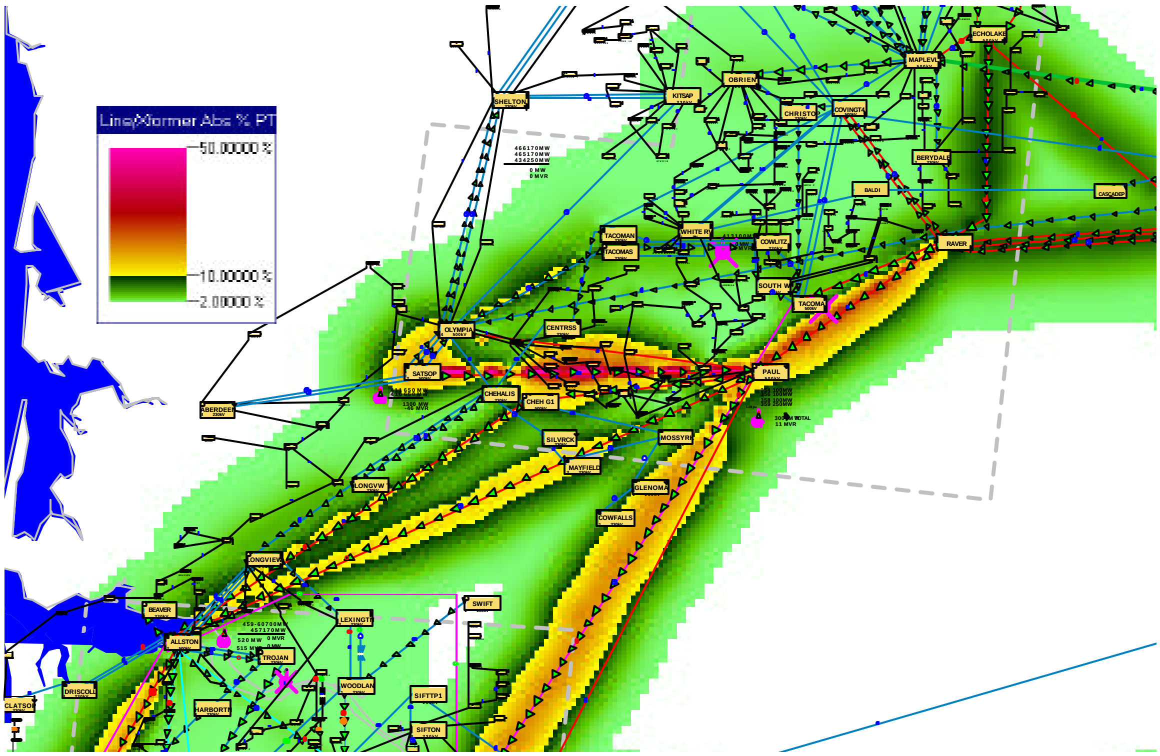


Figure 6.c: PTDF Contouring for Satsop Generation

6.6.2 Contingency Analysis

This section analyses in detail the severe contingencies that affect the I-5 corridor for this state. The Keeler to Pearl contingency is the limiting one in this system state. It creates the following overloads:

Violations for the Keeler to Pearl Outage			
Element	Value	Limit	Percent
FROM MURRAY H TO ST MARYS CKT 1	628.98	523.90	120.06
FROM KEELER TO KEELER CKT 1	1033.52	950.00	108.79
FROM HUBER 2 TO TEK 1 CKT 1	193.97	180.00	107.76
FROM BEAVRTON TO DENNY CKT 1	210.33	197.00	106.77
FROM HARRISON TO HOLLADAY CKT 1	183.38	179.30	102.28

Clearly, Satsop generation creates additional loading in the 230kV system when this line is outaged. Figure 6.d shows the PTDF's for the Satsop to Lower Monumental area when the Keeler to Pearl line is outaged. Figure 6.e shows the corresponding violations.

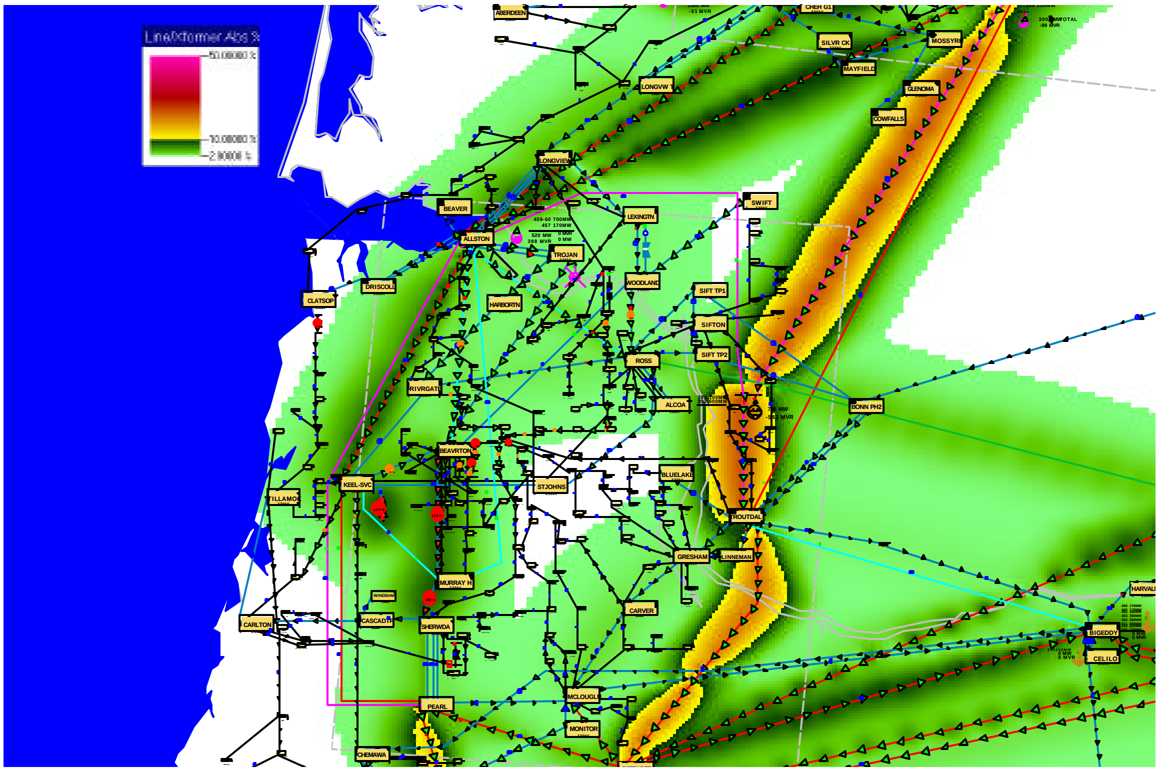


Figure 6d: PTDF Contouring for Keeler to Pearl Outage

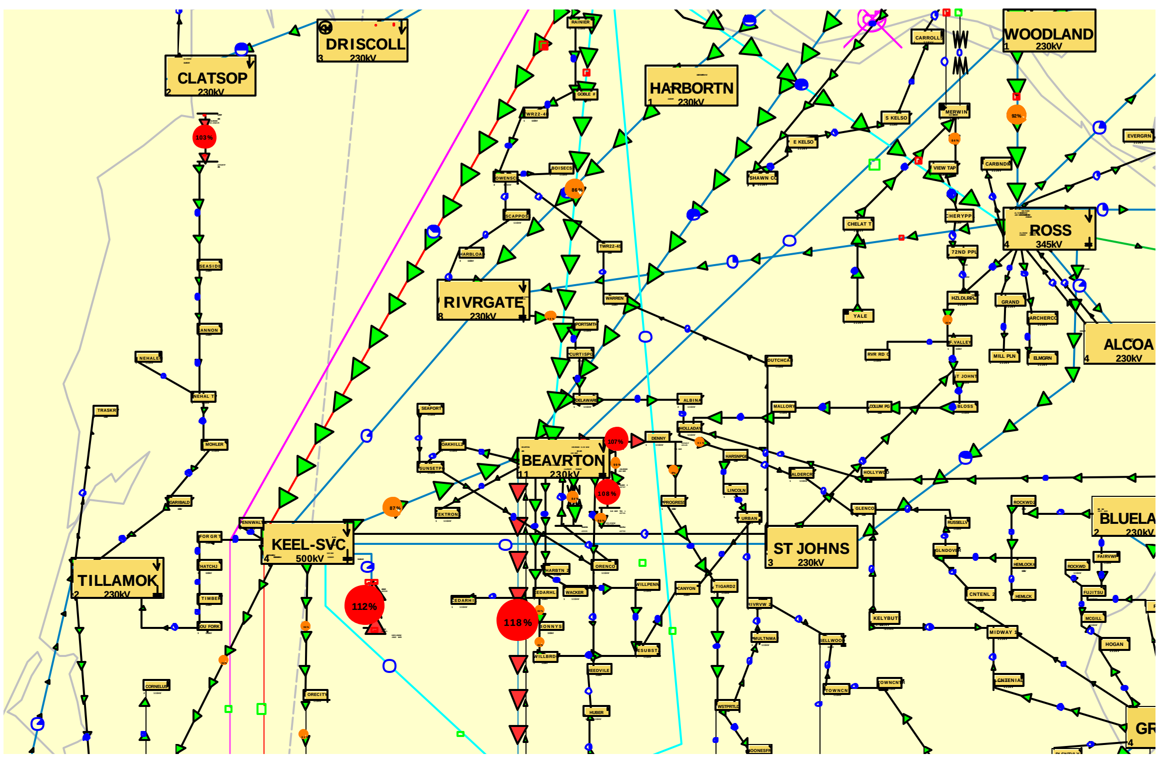


Figure 6.e: Violations for the Keeler to Pearl Outage

The following table presents sample results of TLR sensitivities for the St. Marys to Murray 230kV line for an outage of the Keeler to Pearl 500kV line.

TLR Sensitivities for St. Marys to Murray									
Contingency: Keeler to Pearl									
Number	Name	ID	P Sensitivity	Gen MW	Number	Name	ID	P Sensitivity	Gen MW
43599	TROJAN 1	1	0.163	0	40199	CENTRALA	1	0.107	10
43017	BEAVER	1	0.147	360	47047	GLENOMA	1	0.107	30
43019	BEAVER	1	0.147	135	41803	CHEH ST	1	0.095	230
40043	ALLSTON	1	0.147	520	41801	CHEH G1	1	0.095	195
40671	LONGVIEW	1	0.143	567	41802	CHEH G2	1	0.095	195
47260	WAUNA	1	0.142	27	45039	CENTR G1	1	0.085	692
40309	COWL CCP	1	0.138	100	40821	PAUL	1	0.085	300
45287	SWIFT	1	0.13	300	45041	CENTR G2	1	0.085	692
47216	RVR RD C	1	0.113	0	40007	ABERDEEN	1	0.084	11
45199	MERWIN	1	0.108	20	40947	SATSOP	1	0.083	0
45351	YALE	1	0.108	130	40947	SATSOP	2	0.083	1300
40307	COWFALLS	1	0.107	17	40841	PORT ANG	1	0.081	28.6
46627	MOSSY RK	1	0.107	150	40345	DETROIT	1	-0.039	105
46623	MAYFIELD	1	0.107	40	40941	SANTIAM	1	-0.043	0

The Satsop generation has a sensitivity of 0.083. The new 1300MW produce 108 additional MW in this line in the N/S direction and the overload of this line.

The Allston to Keeler contingency produces the following overloads:

Allston-Keeler Outage Violations			
Element	Value	Limit	Percent
FROM ALLSTON TO ST MARYS CKT 1	575.23	500.00	115.05
FROM CLATSOP TO ASTOR TP CKT 1	128.34	120.00	106.95
FROM ROSS TO WOODLAND CKT 1	449.83	426.30	105.52
FROM KEELER TO RIVRGATE CKT 1	490.75	478.00	102.67

This contingency overloaded the new Allston to St. Marys 230kV line. This line would require upgrade. Figure 6.f shows the post-contingency conditions for an outage of the Allston to Keeler.

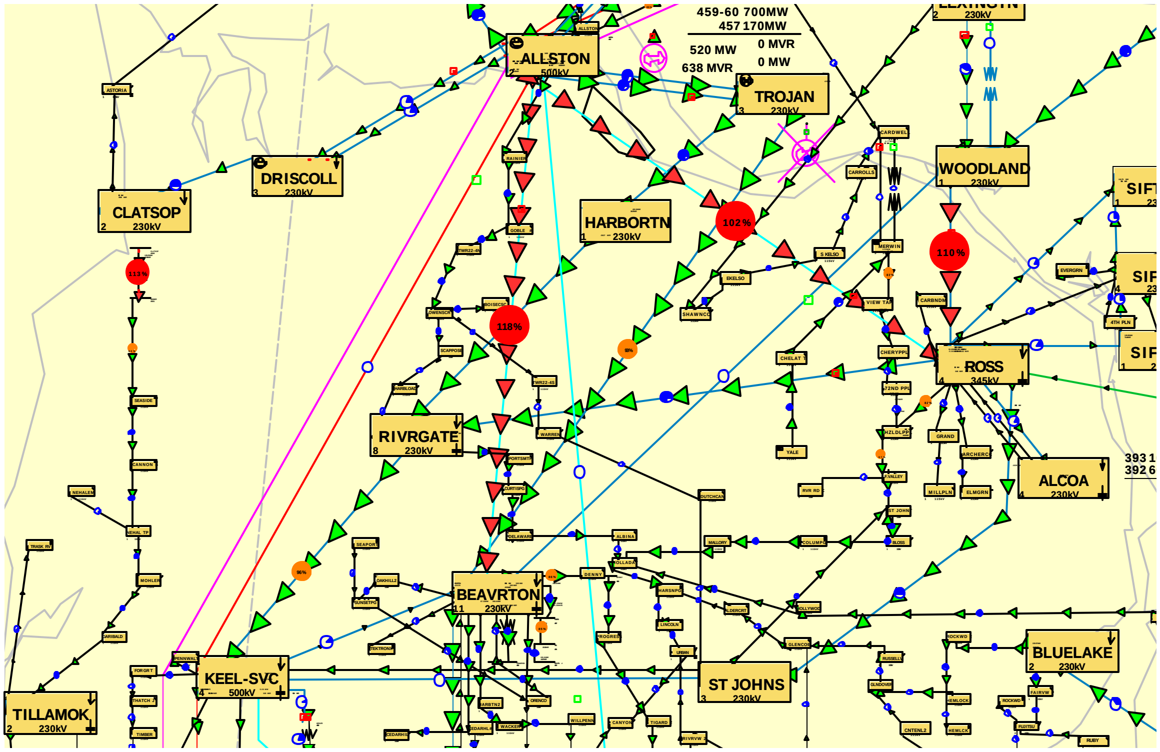


Figure 6.f: Violations for the Allston to Keeler Outage

The LongView transformer outage creates the following overloads:

Longview Transformer Outage Violations			
Element	Value	Limit	Percent
FROM CLATSOP TO ASTOR TP CKT 1	128.24	120.00	106.87
FROM LEXINGTN TO LEXINGTN CKT 1	288.10	281.00	102.53

This sample results provide insight on the loading that Satsop generation creates in the 230kV and 115kV systems in the Portland area.

6.6.3 Proposed System Expansion

One expansion alternative is to include the series capacitors in the Schultz to Vantage and Schultz to Handford 500kV lines. As mentioned in a previous state, this alternative would have high-voltage problems that can be resolved with a new line. If this alternative were pursued, the Allston to Keeler and the Keeler to Pearl contingencies would not create the mentioned overloads in the system.

Another alternative that would support the effect of more generation in the Custer and Sedro region is a new Allston to Pearl 500kV line. This would also avoid the overloads of the Keeler transformers. This implementation is shown in Figure 6.g for an outage of the existing Allston to Keeler. We consider this to be a better alternative and proceed with it.

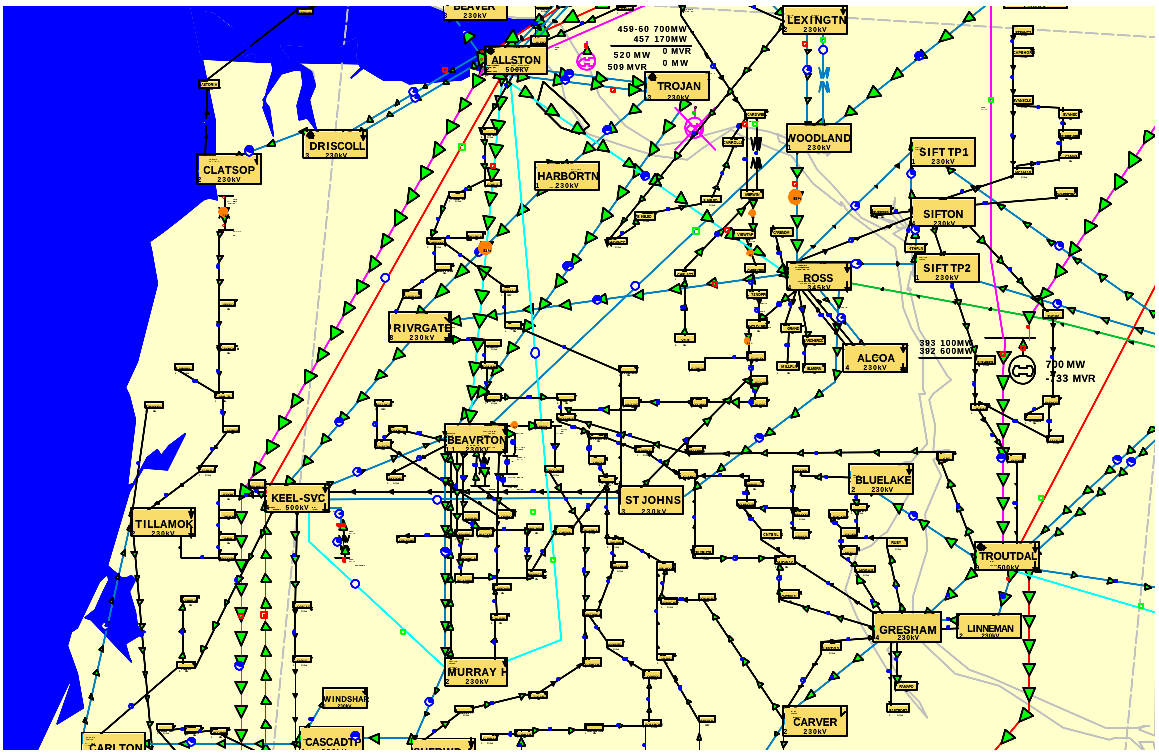


Figure 6.g: System Condition for the Allston to Keeler Outage with Expansion

6.7 System State 7: Cowlitz Generation (100MW) Request 413

6.7.1 Base Case Results

The generation is connected to the Cowlitz 230kV bus. Generation displacement consists in 100MW at McNary. No adjustment in phase shifter control is required for the Ingledow to Custer flow. This state assumes that the new Allston to Pearl 500kV line is in place. The series capacitors from Schultz to Vantage and Schultz to Handford are bypassed. The following figure illustrates the PTDF contouring for Cowlitz generation for the base case.

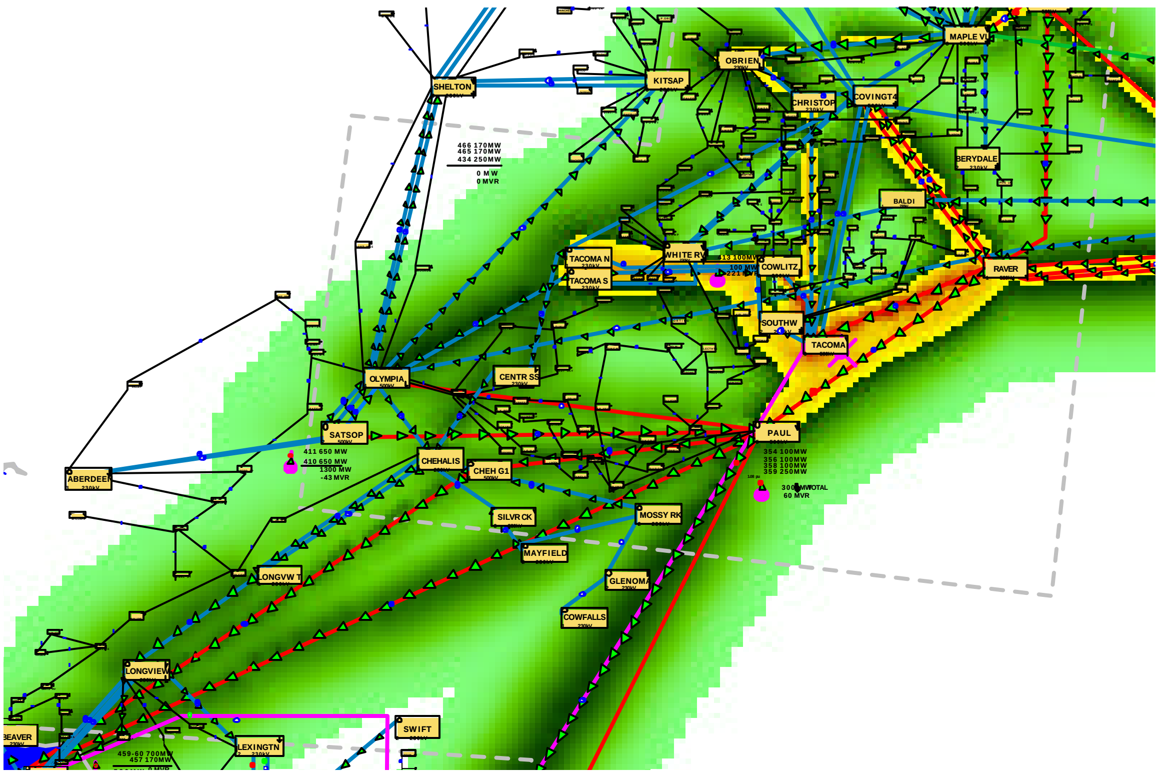


Figure 7: PTDF Contouring for Cowlitz Generation

The figure shows that most of the flow follows the North direction, primarily through the Raver to Schultz 500kV circuits. The generation does not have much impact on the low voltage system of the Portland area. It decreases the flow due to the netting effect. The flow reaches the 500kV bus at Tacoma and then the 500kV system, without causing new violations. The generation produces a counter-flow in the Tacoma transformer and the Tacoma to Cowlitz 230kV line.

6.7.2 Contingency Analysis Results

Contingency analysis indicates very similar results with and without Cowlitz generation. This is expected due to a similar generation pattern and small amount of generation.

6.7.3 System Expansion

No system expansion is needed with 100MW of generation at Cowlitz. A limit is found and system expansion is needed close to the 400MW level, without Satsop generation and a Paul to Raver contingency.

6.8 System State 8: Sedro Generation (600MW) Request 416

6.8.1 Base Case Results

Generation at Sedro contributes to the North to South flow in the I-5 Corridor. It is necessary to consider a worst-case thermal generation pattern by eliminating the reduction of flow across potential constraints due to the netting effect. A reduction in the production to the South of Raver Substation makes more flow come from the North towards the Portland area, creating maximum stress in the North to South direction. A worst-case scenario is created if the following generation is out of service:

Generation Assumed out of Service						
Existing Generation				New Generation		
41801	CHEH G1	195 MW		40043	ALLSTON	520 MW
41802	CHEH G2	195 MW		40821	PAUL	300 MW
41803	CHEH ST	230 MW		79400	ALCOAM	700 MW
45039	CENTR G1	692 MW				
45041	CENTR G2	692 MW				

This aggregate generation must be compensated by bringing back to service the generators that were sequentially displaced up to state 7. Total system losses increase 300MW due to this rearrangement of generation resources. The phase shifter control for the Ingledow to Custer flow is fixed at –7 degrees. Some additional generation is taken from the displaced generation to compensate the losses maintaining Grand Coulee generation constant.

We recall that for this state a third circuit Custer to Monroe is in place as well as the Allston to Pearl 500kV line. There are no violations in the base case. However, preliminary contingency simulations reveal that the outage of Sedro to Murray 230kV line creates an overload in the Sedro to Horse Ranch 230kV line, and vice-versa. The single line outage Custer to Monroe overloads these lines as well as the 115kV lines in the area.

The PTDF contouring for a Sedro to Coyote transfer is illustrated in the following figures. Figure 8.a presents the overall I-5 corridor system. Figure 8.b presents the Sedro-Custer-Monroe area.

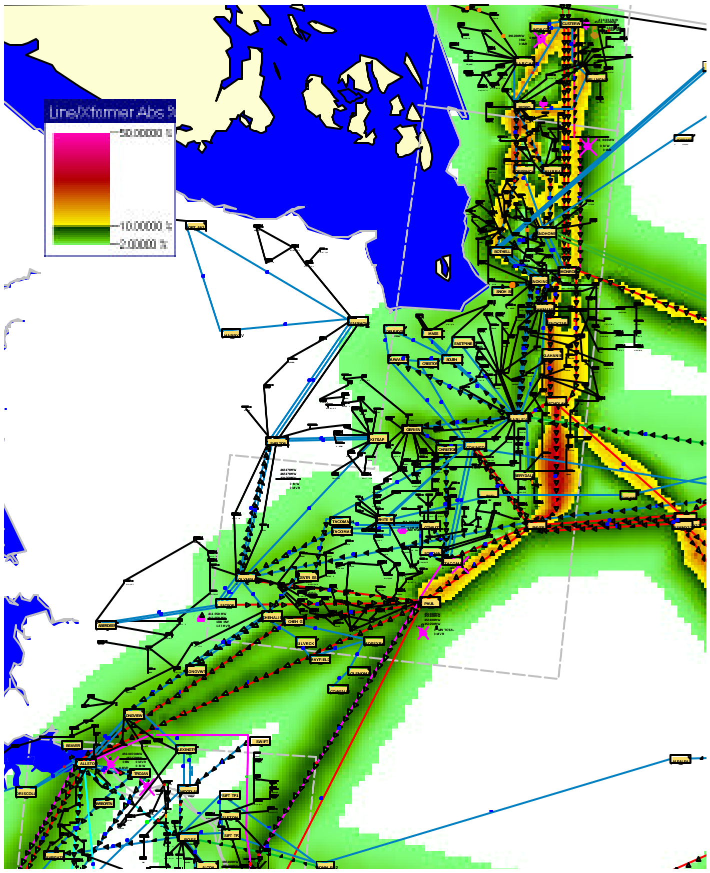


Figure 8.a: PTDF Contouring for Sedro Generation

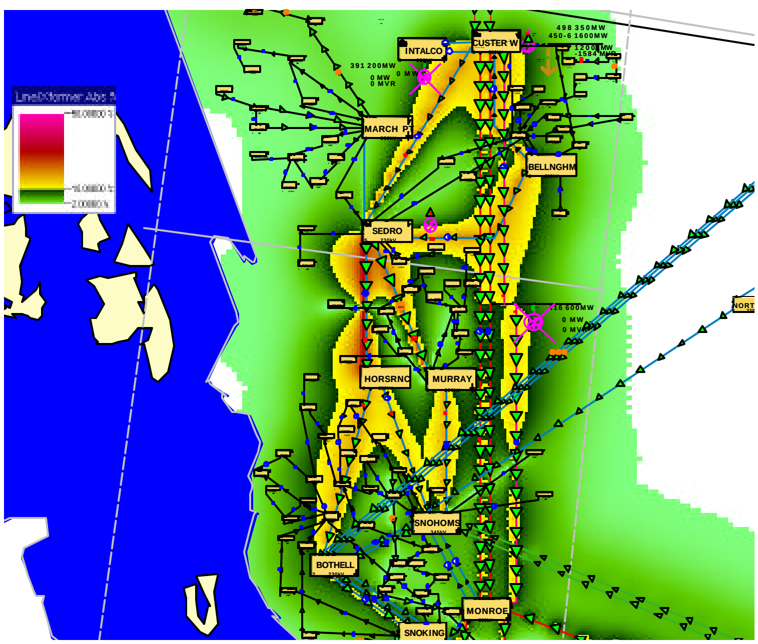


Figure 8.b: PTDF Contouring in the Custer-Monroe Area

The figure above shows that part of the flow loops around following the path Sedro to Custer and then goes back from Custer 500kV to Monroe. Most of the flow goes through the Sedro to Horse Ranch 230kV line. Clearly, system expansion in the 230kV level would be required up to the Monroe substation. An alternative is to connect Sedro the generation to the 500kV system by moving Sedro generation to a junction substation between Custer and Monroe. The junction is located at 40/87 of the distance from Custer to Monroe. The parameters for the resulting line segments are:

Line Parameters				
From	To	R	X	C
Custer W	Sedro Jc	0.000468966	0.00868046	0.749618391
Sedro Jc	Monroe	0.000551034	0.01019954	0.880801609

The PTDF contouring for this new alternative is shown in the following figure.

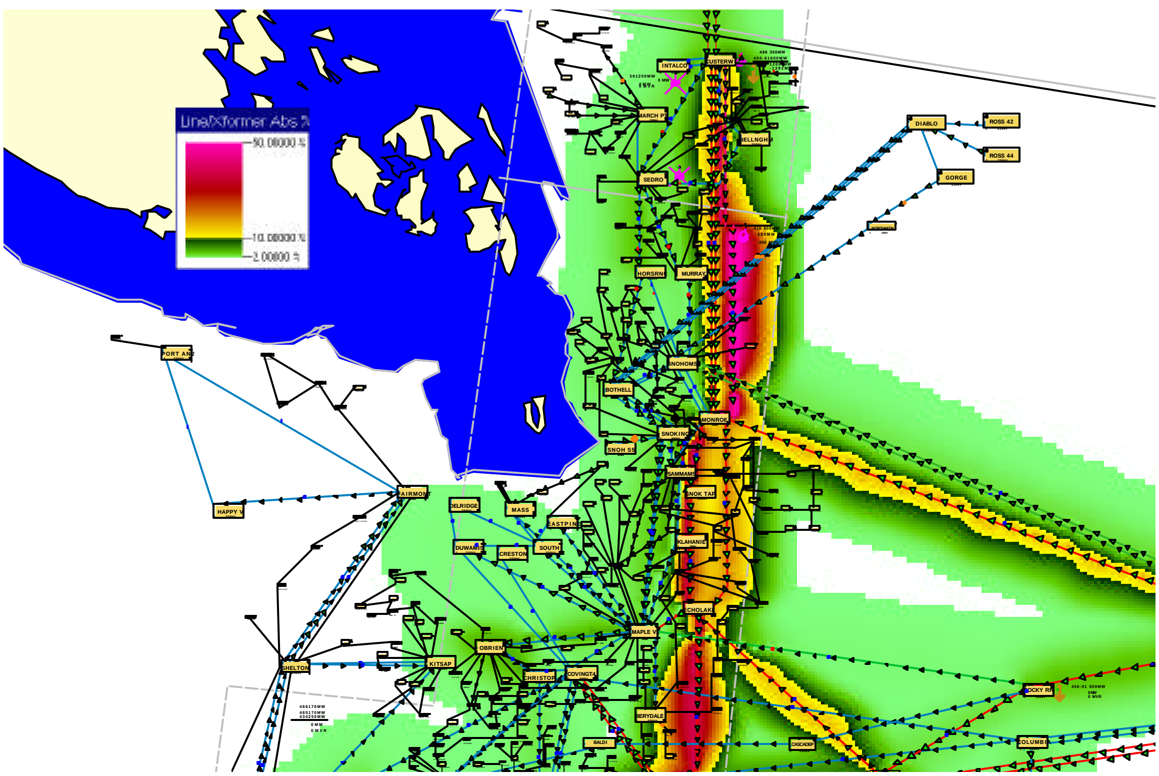


Figure 8.c: PTDF Contouring for Sedro Generation at 40/87 Custer-Monroe

With this option about 35% of the flow still goes through Custer. However, this alternative does not create severe overloads when contingencies occur in that area.

6.8.2 Contingency Analysis

Contingency analysis was performed for several generation patterns. The simulations revealed that Centralia and Chehalis generation hide some violations in the Tacoma area due to the netting effect. Figure 8.d shows the flows in the Tacoma area for an outage of the Raver to Paul 500kV line, without Paul generation.

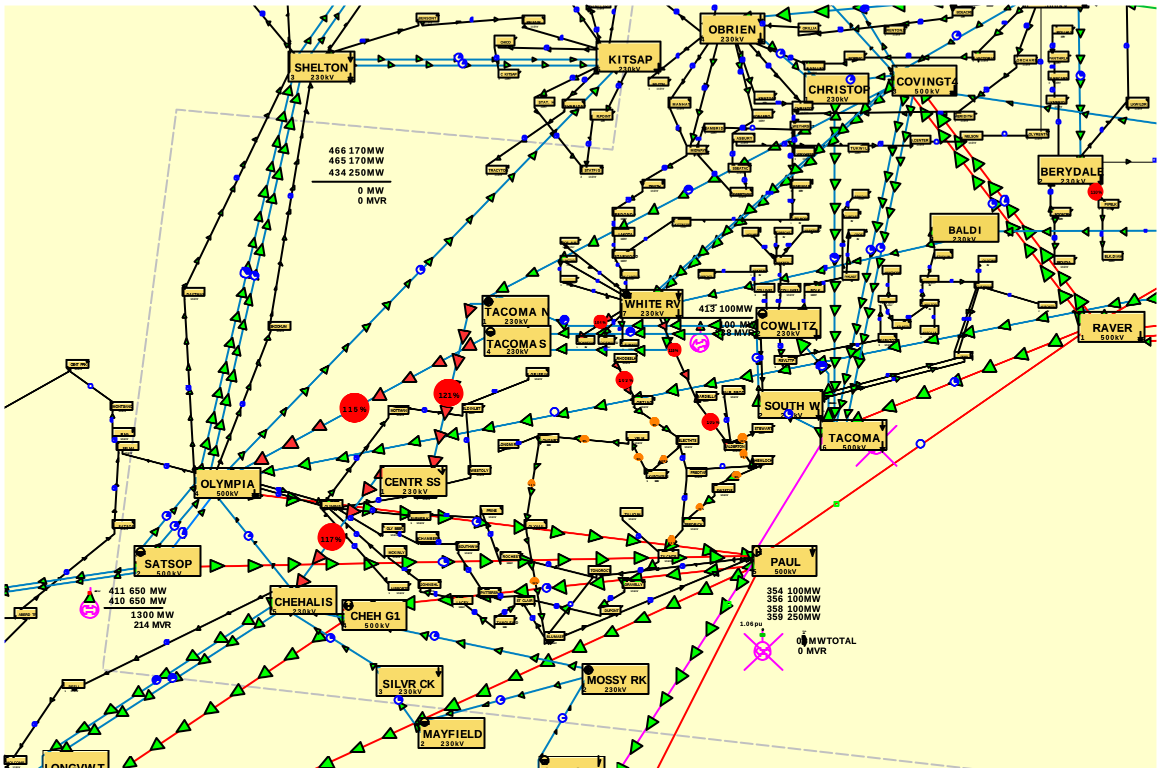


Figure 8.d: Flows in the Tacoma Area for a Paul to Raver Outage

It is apparent that this outage produces considerable overload in the 230kV, 115kV and 59kV system. The following table shows the corresponding overloads.

Severe Violations for a Raver to Paul Outage			
Element	Value	Limit	Percent
FROM FERNHILL TO WHITE RV CKT 1	33.88	20.00	169.38
FROM CENTR SS TO TACOMA N CKT 1	518.13	426.30	121.54
FROM CENTR SS TO CHEHALIS CKT 1	494.87	426.30	116.09
FROM OLYMPIA TO TACOMA S CKT 1	698.84	605.50	115.42
FROM GARDELLA TO WHITE RV CKT 1	126.34	110.00	114.86
FROM RHODESLK TO WR-KCTAP CKT 1	125.76	110.00	114.33
FROM BERRYDAL TO PIPE LK CKT 1	74.70	67.90	110.01
FROM FERNHILL TO SGATE T CKT 1	31.94	30.00	106.47

Although this contingency causes severe violations in this area, TLR sensitivity calculation demonstrates that the contribution of Sedro generation to the loading of these elements is small. System expansion though must address this worst-case scenario for Sedro generation.

The Echo Lake to Snok Tap outage creates the following violations:

Violations for the Echo Lake to Snok Tap Outage

Element	Value	Limit	Percent
FROM MAPLE VL TO SNOK S3 CKT 1	461.24	426.30	108.20
FROM MAPLE VL TO SNOK S1 CKT 2	459.47	426.30	107.78
FROM BROAD ST TO UNIVERSY CKT 1	220.89	218.30	101.18

The following table shows the largest (positive and negative) TLR sensitivities for the Snok S3 to Maple Ville with an outage of the Snok Tap to EchoLake 500kV line.

TLR Sensitivities for Snok S3 to Maple Ville

Contingency: Snok Tap to Echo Lake

Number	Name	ID	P Sens.	MW	- -	Number	Name	ID	P Sens.	MW	- -	Number	Name	ID	P Sens.	MW
46445	SOUTH	1	-0.037	0		40947	SATSOP	1	-0.011	0		42022	SUMAS L	1	0.077	48
42731	WRGEN1-2	1	-0.026	25		45039	CENTR G1	1	-0.01	0		42021	SUMAS 1	1	0.077	83
42733	WRGEN3-4	1	-0.026	25		41801	CHEH G1	1	-0.01	0		42014	ENSERCHL	1	0.078	41
46777	STMPLT2A	1	-0.025	18		41803	CHEH ST	1	-0.01	0		42013	ENSERCH3	1	0.078	37
46778	STMPLT2B	1	-0.025	0		41802	CHEH G2	1	-0.01	0		42012	ENSERCH2	1	0.078	37
46732	LAGRND	1	-0.023	24		45041	CENTR G2	1	-0.01	0		42011	ENSERCH1	1	0.078	37
42711	ELECTRON	1	-0.023	12		40821	PAUL	1	-0.01	0		42124	UP BAKER	1	0.087	81
46672	ALDER12	1	-0.023	12		43017	BEAVER	1	-0.008	360		42121	LO BAKER	1	0.087	59.5
46615	CUSHMN2	1	-0.023	10		43599	TROJAN 1	1	-0.008	0		42134	MRPTGENL	1	0.088	23
46733	LAGRND5	1	-0.023	41		43019	BEAVER	1	-0.008	135		42133	MRPTGEN3	1	0.088	37
46613	CUSHMN1	1	-0.023	8		40043	ALLSTON	1	-0.008	0		42132	MRPTGEN2	1	0.088	37
46671	ALDER11	1	-0.023	25		40309	COWL CCF	1	-0.008	100		42131	MRPTGEN1	1	0.088	37
46607	COWLITZ	1	-0.023	100		40671	LONGVIEW	1	-0.008	567		42112	FREDONA2	1	0.088	100
41053	TACOMA N	1	-0.022	0		47260	WAUNA	1	-0.008	27		42111	FREDONA1	1	0.088	100
41300	XFREDRK	1	-0.022	90		45287	SWIFT	1	-0.007	300		42100	SEDRO	1	0.089	0
41301	XFREDRK	1	-0.022	160		79400	ALCOAM	1	-0.007	0		45850	KIMCLK L	1	0.101	45
40199	CENTRALA	1	-0.012	10		79401	SEDRO	1	0.067	600		45689	JACKSN2	1	0.101	40
47047	GLENOMA	1	-0.012	30		40323	CUSTER W	1	0.068	1200		45687	JACKSN1	1	0.101	40
40841	PORT ANG	1	-0.012	28.6		40573	INTALCO	1	0.072	0		46429	GORGE	1	0.115	170
46623	MAYFIELD	1	-0.012	40		42043	WHITHRN3	1	0.075	74.4		46441	ROSS 44	1	0.116	162
46627	MOSSY RK	1	-0.012	150		42042	WHITHRN2	1	0.075	74.4		46439	ROSS 42	1	0.116	162
40307	COWFALLS	1	-0.012	17		42033	TENASKAL	1	0.076	80		46419	DIABLO	1	0.116	156
40007	ABERDEEN	1	-0.011	11		42032	TENASKA2	1	0.076	82		41326	SNOH S5	1	0.136	500
40947	SATSOP	2	-0.011	1300		42031	TENASKA1	1	0.076	82						

Clearly, the overload in this element would be reduced if the generation that was taken out of service for this base case were brought back into service. We can also see that Tacoma, Custer W, Sedro and Satsop generation increase the loading in this line.

The Snok Tap to Echo Lake contingency overloads the following elements:

Violations for the Snok Tap to Echo Lake Outage

Element	Value	Limit	Percent
FROM MAPLE VL TO SNOK S3 CKT 1	461.24	426.30	108.20
FROM MAPLE VL TO SNOK S1 CKT 2	459.47	426.30	107.78
FROM BROAD ST TO UNIVERSY CKT 1	220.89	218.30	101.18

The base case flows and the post-contingency conditions are shown in Figures 8.e and 8.f.

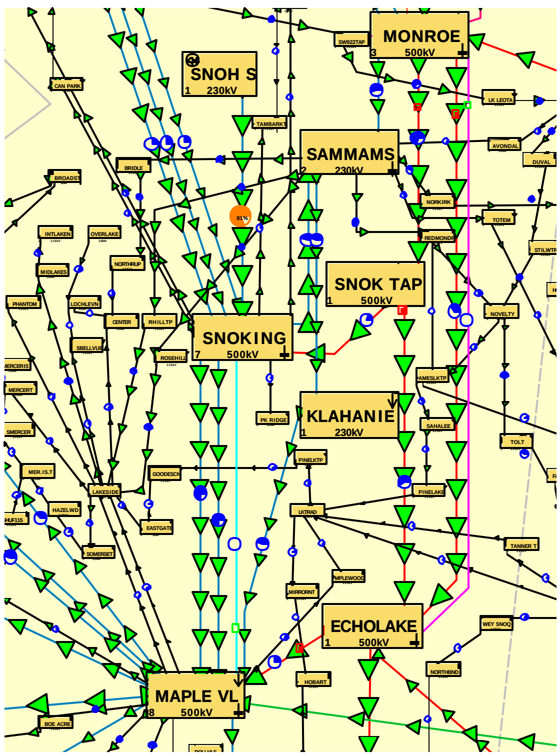


Figure 8.e Base Case Flows

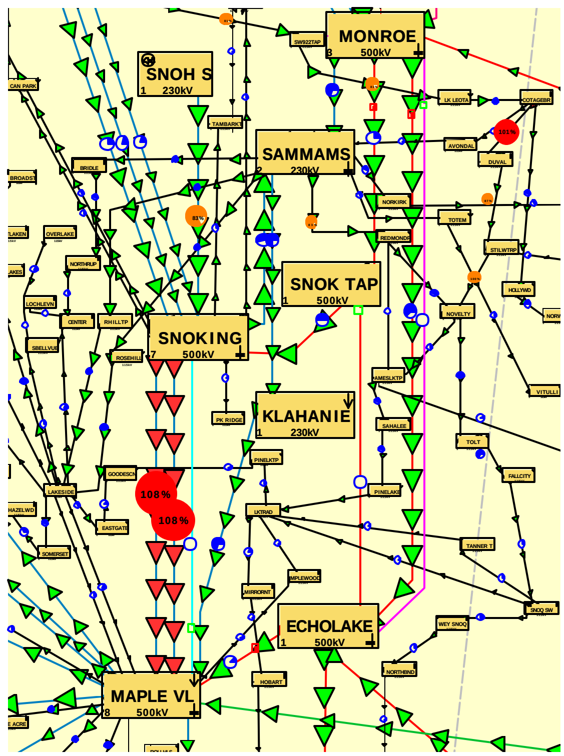


Figure 8.f: Snok Tap to Echo Lake Outage

From the analysis above, it is clear that system expansion must address the violations in the Monroe-Echo Lake area.

The Harvest to O'Brien 115kV line outage causes an overload of 58% in the Midway P to Sweptwng 115kVline. The BoeAero to Harvest 115kV line overloads the same line in 37%.

The Echo Lake to Raver overloads the Berry D to Pipe Lake line in 5.2% and produces a small overload in the Fernhill to White River line.

The cross analysis of overloads versus contingencies reveals that the following contingencies overload the Fernhill to White River 115kV line:

Contingencies that Overload Fernhill to White River			
Label	Value	Limit	Percent
L40821PAUL-40869RAVERC1	33.88	20.00	169.38
X42803STCLAIR-42804STCLAIRC1	21.53	20.00	107.67
L40793OLYMPIA-41055TACOMASC1	21.44	20.00	107.22
L42720FREDRICK-42782TILCMTPC1	20.94	20.00	104.72
L42759GRAVELLY-42782TILCMTPC1	20.75	20.00	103.75
L42752DUPONT-42759GRAVELLYC1	20.58	20.00	102.90
L42752DUPONT-42772QUARRYC1	20.37	20.00	101.83
L42772QUARRY-42803STCLAIRC1	20.21	20.00	101.03
L40381ECHOLAKE-40869RAVERC1	20.06	20.00	100.28

The Gardella to White River presents overloads with the following contingencies:

Contingencies that Overload Gardella to White River			
Label	Value	Limit	Percent
L42779SUMNER-42701WHITERVC1	127.55	110.00	115.95
L40821PAUL-40869RAVERC1	126.34	110.00	114.86
L42753EDGEWOOD-42701WHITERVC1	123.67	110.00	112.43
L42771PIONEER-42779SUMNERC1	120.18	110.00	109.25
L42771PIONEER-42788WOODLNDC1	120.18	110.00	109.25
L42747CEDARHST-42753EDGEWOODC1	119.55	110.00	108.68
L42787WOODLDSW-42788WOODLNDC1	111.83	110.00	101.66
L42757FRUTLAND-42787WOODLDSWC1	111.82	110.00	101.65
L42747CEDARHST-42778STEWARTC1	110.61	110.00	100.56

There are a number of less severe contingencies and overloads, most of them occurring in the Tacoma area.

6.8.3 Proposed System Expansion

System expansion for this state has to address the overloads created by the Paul to Raver contingency as well as the overloads in the Monroe-Echo Lake area.

An analysis of the Paul to Raver contingency determines that the Sedro flow that would go through this line, nearly 200MW, is redistributed across the 230, 115 and 59kV systems in the Tacoma area. Minimum system expansion includes a new path for this flow. Since in a future state new generation will be included at Tacoma, a convenient alternative is to create a new 500kV line Tacoma to Paul to form the path Raver to Tacoma to Paul. We note that even though most of these overloads appear due to the generation out of service at Chehalis and Central SS generation, this line is needed for the Sedro generation and will be more important for the Tacoma generation. The following table shows TLR sensitivities for Centr SS to Tacoma 230kV line when the Paul to Raver contingency is simulated, with respect to the generation taken out of service.

TLR Sensitivities for CentrSS to Tacoma

For Generation out of Service
Contingency: Paul to Raver.

Number	Name	ID	P Sensitivity	Number	Name	ID	P Sensitivity
40043	ALLSTON	1	0.061	41802	CHEH G2	1	0.045
40947	SATSOP	2	0.048	45039	CENTR G1	1	0.044
41803	CHEH ST	1	0.045	45041	CENTR G2	1	0.044
41801	CHEH G1	1	0.045	40821	PAUL	1	0.044

The sum of these sensitivities represents 40.7% of the line. A similar effect occurs in other lines that become overloaded with the Raver to Paul outage. When this generation is in place, Sedro generation would require only the third circuit from Custer to Monroe (state 4) with the junction substation for Sedro and not the addition of a Tacoma to Paul 500kV line due to the netting effect of these generators South of Paul.

A new path for the Echo Lake to SnokTap and Monroe to Echo Lake contingencies is also needed. This is achieved by a new Monroe to Echolake 500kV circuit.

6.9 System State 9: Tacoma Generation (250MW) Request 434

6.9.1 Base Case Results

Tacoma generation was modeled considering the following thermal generation disconnected in order to reduce the netting effect on potentially limiting branches.

Generation Assumed out of Service					
Existing Generation			New Generation		
41801	CHEH G1	195 MW	40043	ALLSTON	520 MW
41802	CHEH G2	195 MW	40821	PAUL	300 MW
41803	CHEH ST	230 MW	79400	ALCOAM	700 MW
45039	CENTR G1	692 MW			
45041	CENTR G2	692 MW			

In order to confirm the need of the Tacoma to Paul 500kV line, the base case of this state did not include this line. The generation displacement consisted in the Herm S unit. No phase-shifter adjustment was necessary. Figure 9.a shows the PTDF contouring for the new generation.

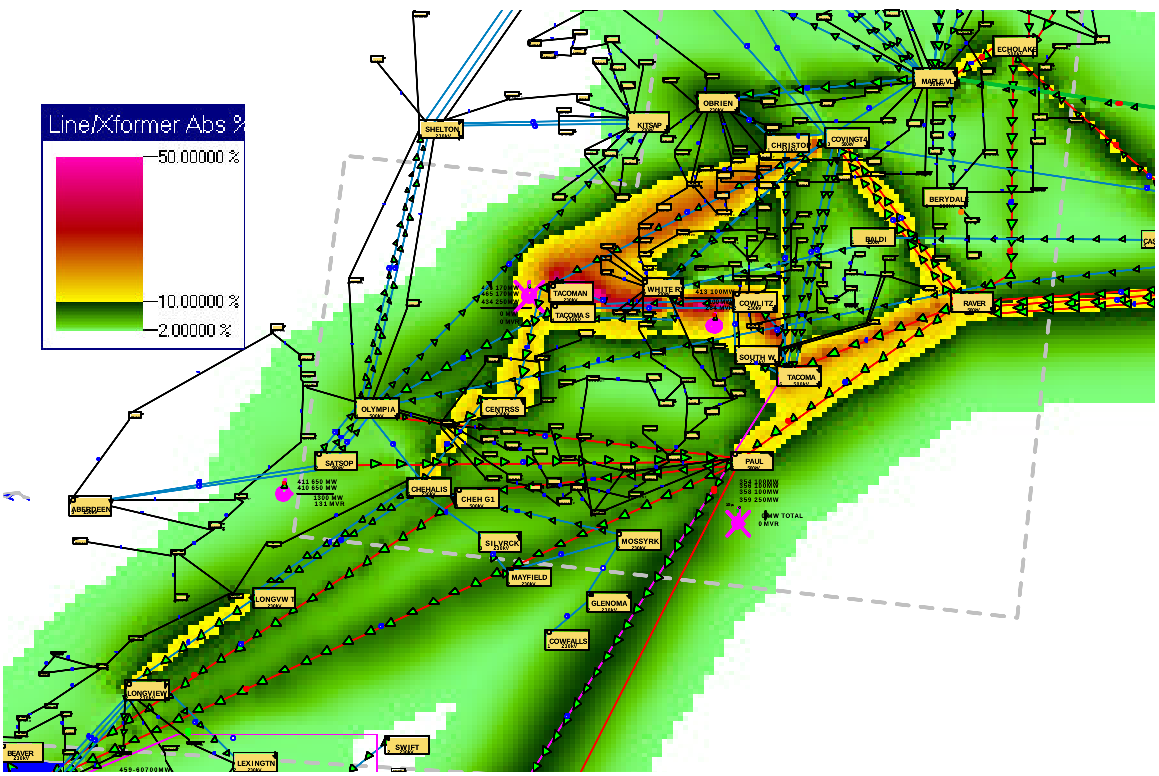


Figure 9.a: PTDF Contouring for Generation at Tacoma

Some 35% of the transferred flow takes North paths either through Tacoma to Covington to Raver or through Echo Lake to Schultz. Around 35% of the transfer takes the East path Tacoma to Cowlitz to Raver. The rest of the flow goes towards the South through the 230kV path Centralia to Chehalis to Longview. Clearly, Tacoma generation will stress this path in the case of the Raver to Paul contingency.

6.9.2 Contingency Analysis

The Paul to Raver 500kV outage (without the Tacoma to Paul 500kV line) is the most severe contingency in this state. It creates the following overloads:

Violations for the Raver to Paul Outage

Element	Value	Limit	Percent
FROM FERNHILL TO WHITE RV CKT 1	34.66	20.00	173.29
FROM CENTR SS TO TACOMA N CKT 1	548.80	426.30	128.74
FROM CENTR SS TO CHEHALIS CKT 1	523.50	426.30	122.80
FROM OLYMPIA TO TACOMA S CKT 1	725.05	605.50	119.74
FROM RHODESLK TO WR-KCTAP CKT 1	128.53	110.00	116.84
FROM GARDELLA TO WHITE RV CKT 1	128.44	110.00	116.76
FROM BERRYDAL TO PIPE LK CKT 1	74.69	67.90	109.99
FROM FERNHILL TO SGATE T CKT 1	32.67	30.00	108.91
FROM BONNEYLK TO WHITE RV CKT 1	117.94	110.00	107.22
FROM ALDERTON TO GARDELLA CKT 1	117.78	110.00	107.07
FROM ORTING TO RHODESLK CKT 1	115.81	110.00	105.28
FROM HOLDN TP TO SGATE T CKT 1	30.90	30.00	103.01
FROM SCHULTZ TO HANFORD CKT 1	2046.39	2000.00	102.32
FROM BONNEYLK TO WR-KCTAP CKT 1	111.25	110.00	101.13
FROM ELECTHTS TO KAPOWSIN CKT 1	109.13	108.00	101.05
FROM BENEWAH TO TEKOA CKT 1	50.28	50.20	100.16

In the base case, the Paul to Raver line is loaded 80% with a flow of 2150MW. This flow is considerably high and as shown, the contingency condition creates overloads, which should be mitigated by means of substantial system expansion. The new Monroe to Echo Lake circuit implemented in the previous state is required to avoid contingencies in the Echo Lake area. These overloads are not caused directly by Sedro or Tacoma generation, but rather by disconnecting generation to the South and having generation to the North connected. The mentioned contingency condition for an outage of the Raver to Paul line (without the Tacoma to Paul of state 8) is shown in Figure 9.b.

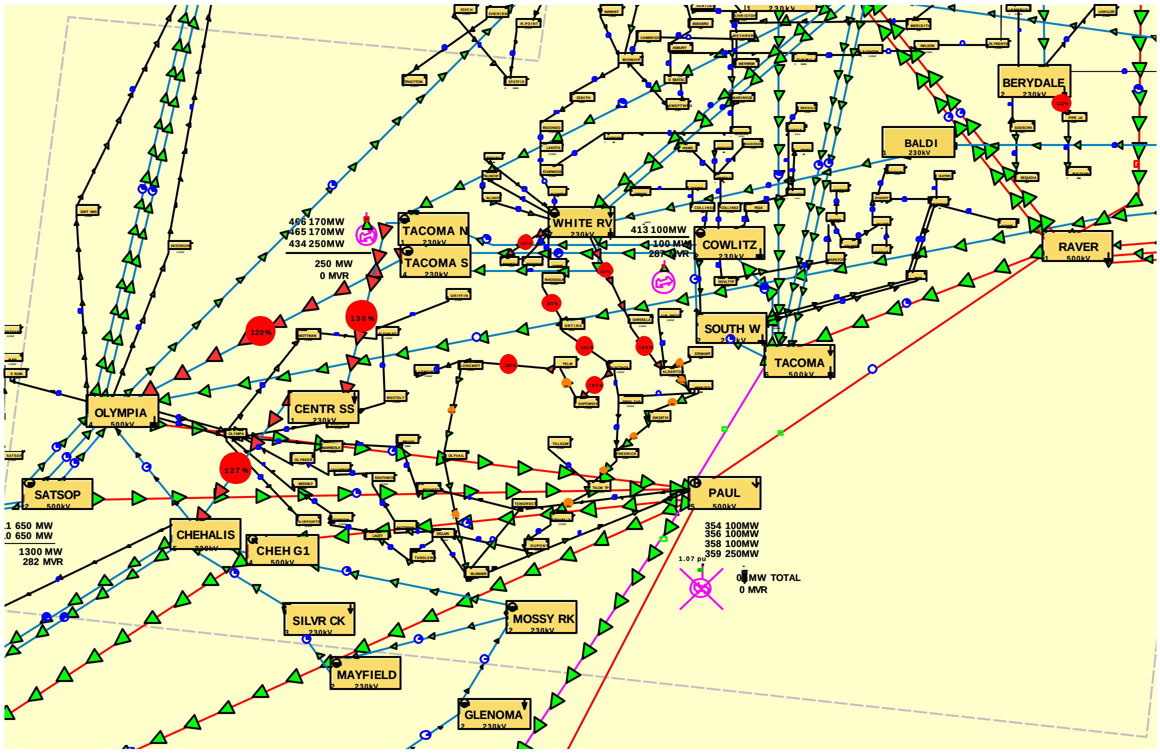


Figure 9.b: System Condition for Raver to Paul outage

This clearly indicates that the Tacoma to Paul line is needed. The difference in line flows of Figure 9.b with respect to Figure 8.d is due to the Tacoma generation, exclusively.

6.9.3 Proposed System Expansion

Generation North of Paul would require additional system expansion for a scenario in which Centralia and Chehalis generation is off, and there is no new (Allston, Paul, Trojan and Alcoa) generation. In such conditions, the new Tacoma to Paul 500kV line is required to mitigate the Paul to Raver contingency. This new line has per unit parameters: R= 0.00060, X=0.01075, and C=0.97040. A rating of 4000 MVA is assumed.

When this line was implemented in the model, it took nearly 1500MW, leaving the Raver to Paul with 1420MW of N/S flow. The Raver to Paul outage did not cause violations with this expansion. We recall that this line was needed for state 8 in order to mitigate some of the effect of additional N/S flows created by generation pattern for Sedro.

6.10 System State 10: Santiam Generation (600MW) Request 435

6.10.1 Base Case Results

Santiam generation was modeled as directly connected to the 500kV bus. Most of the flow goes to the East following the 500kV system from Marion to Big Eddy to Ashe to Lower Monumental. About 25% of the flow goes to the North through the Marion to Pearl to Allston path. The PTDF contouring for this generation is shown in the next figure.

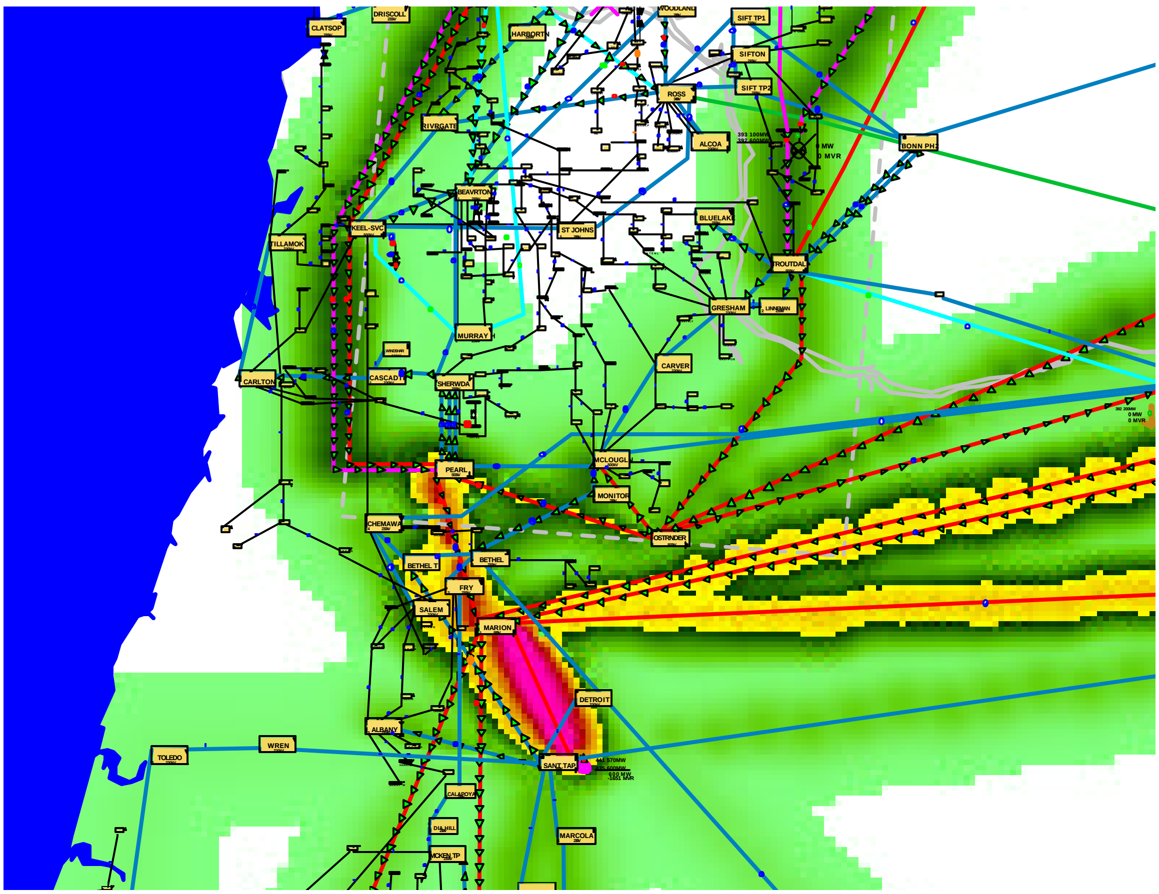


Figure 10.a: PTDF Contouring for Generation at Santiam

The distribution of flow has the following effects:

a) Santiam generation tends to counteract the North to South flow to the North of this substation. When the North to South flow due to bulk power decreases, some of the lines North of Santiam may not support the S/N flow due to the 600MW of generation. In order to model such conditions, a base case (state 10.A) was built by removing the following generation North of Santiam:

Generation Assumed out of Service		
41801	CHEH G1	195 MW
41802	CHEH G2	195 MW
41803	CHEH ST	230 MW
45039	CENTR G1	692 MW
45041	CENTR G2	692 MW
40043	ALLSTON	520 MW
40821	PAUL	300 MW
79400	ALCOAM	700 MW

The displacement for this state corresponds to generation at Rath.

b) Santiam generation contributes to the N/S flow South of Santiam. For this area, the worst-case condition (state 10.B) is obtained by maximizing the N/S flows in the I5 corridor. This is achieved by connecting the generation in the previous table as well all the generation in the sequence up to state 10.

6.10.2 Contingency Analysis, State 10.A

Contingency analysis reveals the following severe contingencies in the I5 corridor:

The RedmondP to Sammamsh outage causes overloads in the following 115kV lines: 42% in the Novelty to Stilwtrp, 40% in the CotagerBr to Duval, and 25% in the Duval to Silwtrp. This is an existing problem not related to the new I-5 corridor. We assume that there is a second 115kV line from RedmondP to Sammamsh.

An outage of McLaughlin to Monitor 230kV overloads Bethel T to Santiam 230kV line in 8%. This overload is caused by Santiam generation.

The Alvey to Dummy 105 (Marion) 500kV line outage overloads the Albany to Hazelwood 115kV line in 10%. This is due to Santiam generation.

A cross analysis of overloads versus contingencies reveals that the Albany to Hazelwood 115kV line is overloaded for the following contingencies:

Contingencies that overload Albany to Hazelwood				
Contingency Label	Category	Value	Limit	Percent
L40025ALBANY -47531LOCHNERC1	Branch MVA	209.08	200.80	104.12
L40049ALVEY -46291MCKENTPC1	Branch MVA	208.18	200.80	103.68
L40051ALVEY -40714DUMMY105C1	Branch MVA	222.41	200.80	110.76
L40435FOSTER-45285SWEETHMC1	Branch MVA	202.06	200.80	100.63
L40447FROMAN-40641LEBANONC1	Branch MVA	203.73	200.80	101.46
L40447FROMAN-47531LOCHNERC1	Branch MVA	205.76	200.80	102.47
L40714DUMMY105-40699MARIONC1	Branch MVA	222.41	200.80	110.76
L43039BETHEL-45111FRYC1	Branch MVA	250.89	200.80	124.95
L43041BETHELT-40939SANTIAMC1	Branch MVA	207.42	200.80	103.30
L45031CALAPOYA-45089DIAHILLC1	Branch MVA	213.38	200.80	106.26
L45089DIAHILL-46291MCKENTPC1	Branch MVA	228.20	200.80	113.65
X45109FRY -45111FRYC1	Branch MVA	205.27	200.80	102.22
X45109FRY -45111FRYC2	Branch MVA	207.07	200.80	103.12

The Clatsop 230 to Astor 115kV transformer is overloaded with the following contingencies: 5% for Allston to Delena, 4% for Clatskan to Delena, and 4% for Longview to NysTap, Ckt 4. These overloads are due to the new I-5 generation and Santiam has a small sensitivity.

The Midway P to Sweptwng 115kV line is overloaded in 58% for Harvest to O'Brien outage and 37% for the Boeaero to Harvest outage. These violations are not due to the Santiam generation but to bulk power.

6.10.3 Proposed System Expansion, State 10.A

The limiting contingency is the Bethel to Fry. This condition is shown in Figure 10.b

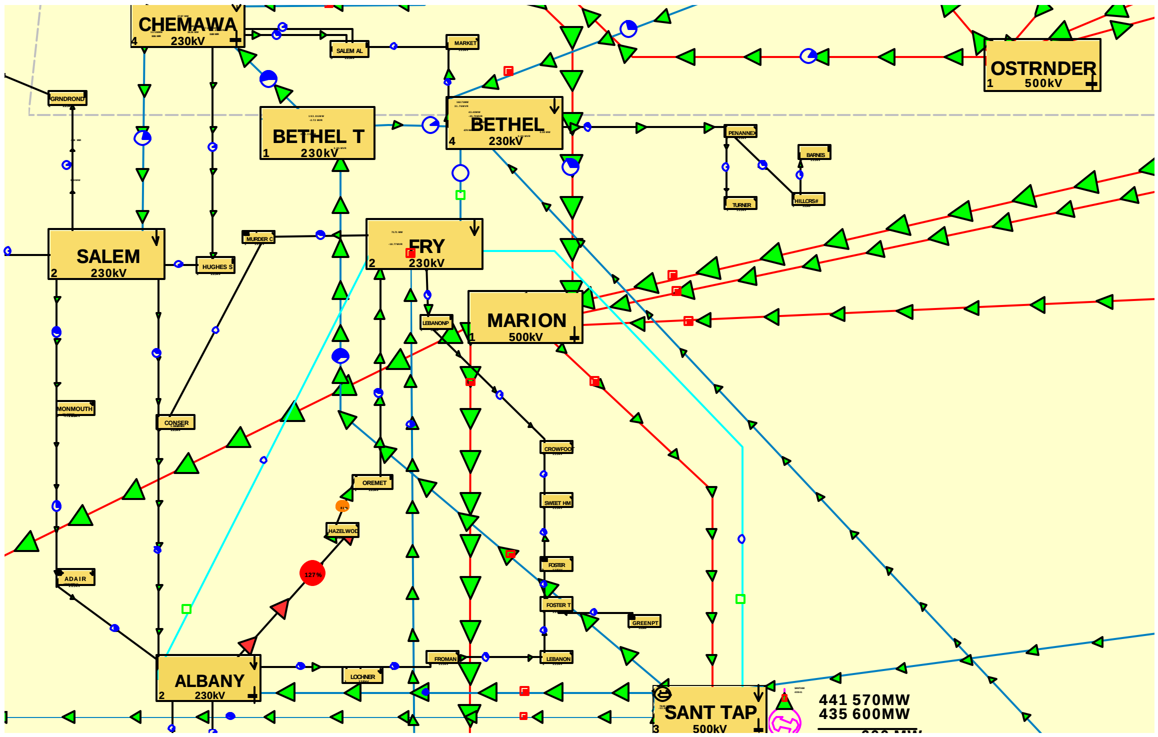


Figure 10.b: System Conditions for an outage of Bethel to Fry

The limiting element in the system is the Albany to Hazelwood 115kV line. This line is loaded at 99% in the base case. Sectionalizing a circuit at the 115kV line is possible. However, the Albany to Hazelwood line is still overloaded for other contingencies. An alternative is a new Santiam to Fry 230kV line, which would form a parallel circuit to the Santiam to Bethel path. This line would have parameters R=0.003, X= 0.02, C= 0.04 and MVA rating= 450.0.

6.10.4 Contingency Analysis, State 10.B

For this state, the generation listed in section 10.6.1 was put back into service. Due to the large amount of generation in the I5 corridor, it is necessary to decrease the imports from Montana to 1000MW. Generation displacement corresponds to all the generation in the displacement sequence at zero, except for generation at Colstrip. This state included the new Santiam to Fry 230kV line modeled in state 10.A. The base case did not present violations.

The contingency analysis determines the following contingencies:

The Big Eddy to Ostrander 500kV line presents an 12% overload for an outage of the Marion to Pearl 500kV line. This is shown in Figure 10.c

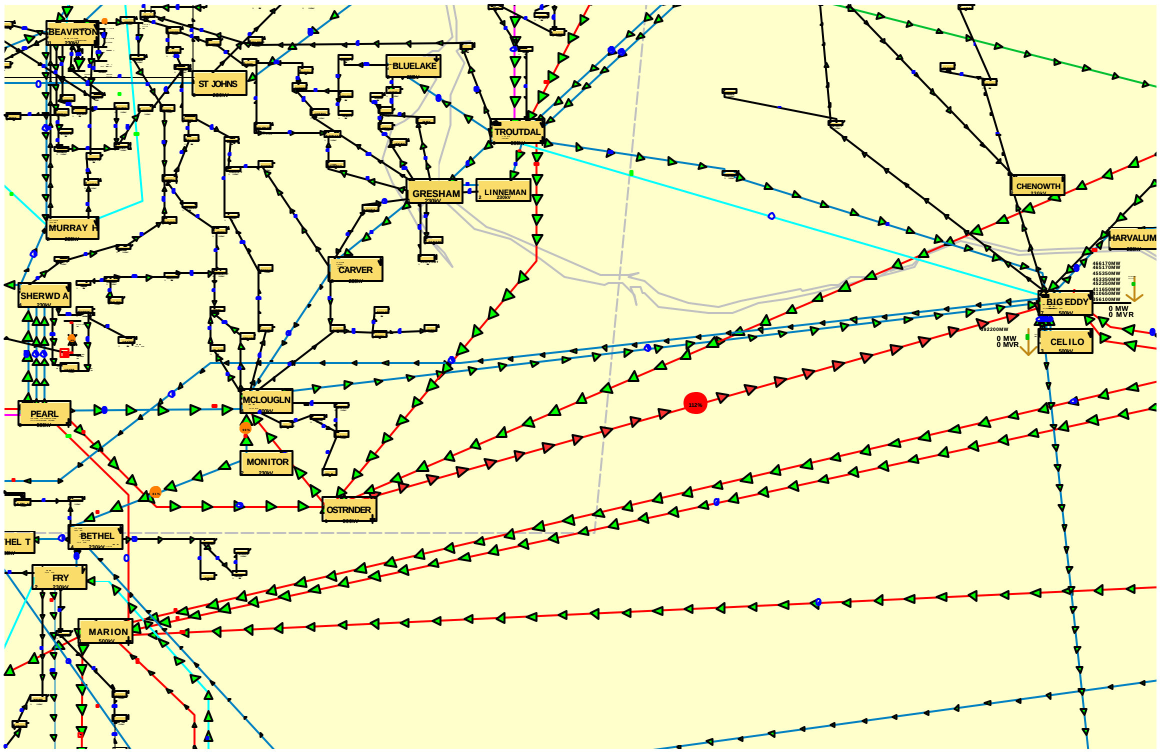


Figure 10.c: System Conditions for an outage of Mario to Pearl

Each of the Lonepine to Meridian P 500kV line circuits is overloaded in 27% with an outage of the second circuit.

The Sammamsh transformer outage overloads the parallel transformer in 26%. The Sammamsh overloads were present at state 0 but were not addressed since more severe overloads (those that occur for more than 3 contingencies) drove the system expansion at that state. The TLR sensitivities for this line show that without Sedro generation the overload is close to 10%. Thus, upgrade of the Sammamsh transformer is assigned to the original case (state 0). An upgrade to 450MVA (from 335MVA) is required.

6.10.5 System Expansion, State 10.B

We can see that the change in the generation pattern drastically modifies the loading in the area South of Paul. The mentioned violations are not produced by Santiam, since the Santiam flow tends to counteract the N/S flow.

The Lexington upgrade is avoided using a phase shifter Lexington to Woodland and a parallel phase shifter Cardwell to Merwin. This phase shifter regulates the amount of power that reached Ross substation.

The Big Eddy to Ostrander 500kV requires an upgrade to avoid overload for the Marion to Pearl 500kV outage. The current limit of 900MVA is upgraded to the 1500MVA level.

6.11 System State 11: Santiam Generation (570MW) Request 441

6.11.1 Base Case Results

This case is an extension of system state 10, with increased generation at Santiam for a total of 1170MW. Generation displacement includes changes in the imports from Montana in order to simulate additional generation displacement. As described in state 10.B, the worst-case condition is given by all the generation of the I5 corridor in place. However, since there may be hidden conditions due to the netting effect, we test also the extension of state 10A, with increased generation at Santiam.

The base case did not present violations.

6.11.2 Contingency Analysis: State 11.A

The worst contingency for this case is the Alvey to Marion 500kV outage, which causes the overloads in Santiam to Fry and Santiam transformer. This result confirms the fact that expansion was needed for the 600MW level generation at Santiam. This new Santiam to Fry 230kV line assumed a 400MVA rating. This can be upgraded to the 600MVA rating level.

The Santiam transformer is also overload. This occurs because our model connects the generator directly to the 500kV bus. Thus, all the new generation has to go through this transformer to reach the 230kV system. We could assume that the step transformer will be connected to the 230kV bus instead. This would be consistent with system expansion that provides a way out for the generation at the 230kV level. Additional system expansion would be required, otherwise.

Other relevant overload occurs in the Keeler transformers. The outage of one of the 230 to 115kV transformers overloads the parallel transformer in 13%. This occurs due to the negative sensitivities of the generation considered out of service for the generation pattern and a positive sensitivity of Santiam generation. This is shown in Figure 11.

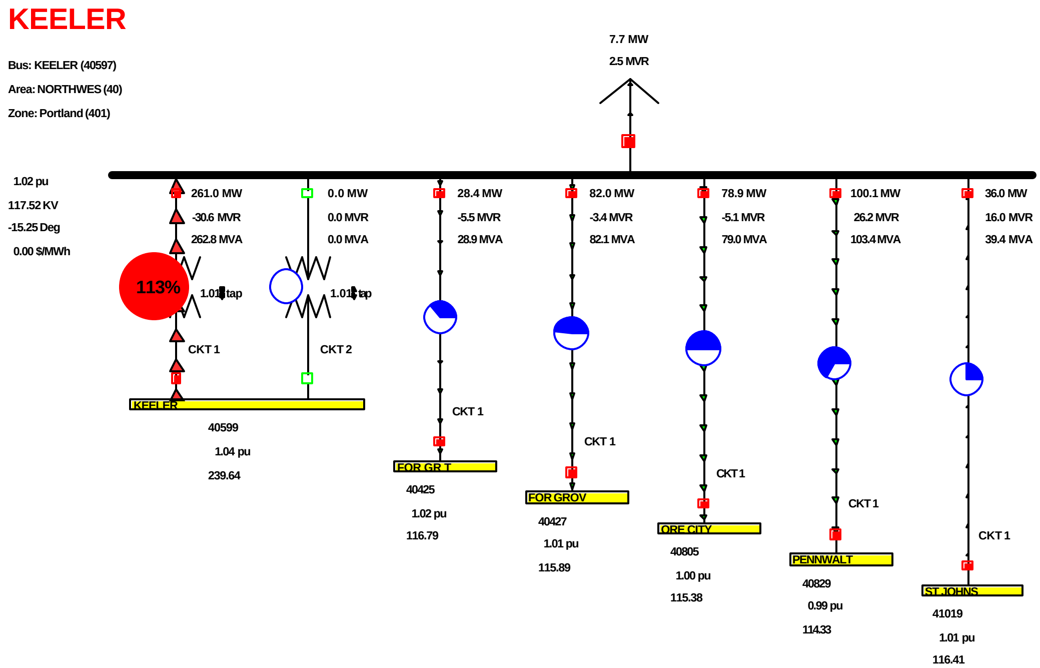


Figure 11: Keeler Bus View with a Keeler Transformer Outage

6.11.3 Proposed System Expansion: State 11.A

A 600MVA rating for the Santiam to Fry 230kV line is required.

We assume that the Keeler transformers are scaled in 25%. We change the parameters:

Transformer Parameters								
From Number	From Name	To Number	To Name	Circuit	R	X	C	Lim A MVA
40599	KEELER	40597.00	KEELER	1.00	0.0011	0.02506	0	233
40599	KEELER	40597.00	KEELER	2.00	0.00063	0.02827	0	302

To be the following:

New Transformer Parameters								
From Number	From Name	To Number	To Name	Circuit	R	X	C	Lim A MVA
40599	KEELER	40597.00	KEELER	1.00	0.00137	0.03132	0	290
40599	KEELER	40597.00	KEELER	2.00	0.00079	0.03534	0	377

The following table shows TLR sensitivities for these Keeler transformers:

TLR Sensitivities for one Keeler Transformer							
Contingency: Lexington Transformer							
Number	Name	P Sensitivity	Gen MW	Number	Name	P Sensitivity	Gen MW
40941	SANTIAM	0.002	1170	45041	CENTR G2	-0.007	0
40947	SATSOP	-0.006	0	40671	LONGVIEW	-0.007	567
40307	COWFALLS	-0.006	17	41801	CHEH G1	-0.007	0
40841	PORT ANG	-0.006	28.6	41803	CHEH ST	-0.007	0
46623	MAYFIELD	-0.006	40	45039	CENTR G1	-0.007	0
40199	CENTRALA	-0.006	10	40043	ALLSTON	-0.009	0
46627	MOSSY RK	-0.006	150	43017	BEAVER	-0.009	360
40007	ABERDEEN	-0.006	11	43019	BEAVER	-0.009	135
40947	SATSOP	-0.006	1300	43599	TROJAN 1	-0.012	0
41802	CHEH G2	-0.007	0				

It is clear that the 1170additional MW at Santiam create this overload for the generation pattern considered for this state.

6.11.4 Contingency Analysis: State 11.B

The contingency analysis for this state utilizes the same base case of state 10.B, but with increased generation at Santiam (1170MW level) and generation displaced in Montana (Colstrip). The results are similar to the ones obtained for the state 10.B, presenting fewer overloads in the Portland area and additional overloads to the East and South of Marion. TLR sensitivities are similar.

6.11.5 Proposed System Expansion: State 11.B

No system expansion is required beyond the additions of state 11.A and 10.B.

6.12 System State 12: Custer Generation (1600MW) Request 451-454

6.12.1 Base Case Results

The base case for state 12 is set up as follows:

a) Since a considerably large amount of new generation is included at this state, the adjustment of the imports and exports levels to and from BPA area is needed in order to change the primary level of generation displacement used for states 1 to 11 to a new base set point (see table on section 3). We consider here the following assumptions: Imports from Montana are changed to be exports of 1000MW. Imports from Idaho are changed to be exports of 1000MW. Exports to California are increased from the 3900MW to the 4500MW level.

b) Imports/exports are balanced by sequentially reconnecting displaced generation.

c) Generation at Centralia and Chehalis are back in place to model the N/S worst-case condition.

d) The phase shifter for the Ingledow-Custer flow is set up at +20 degrees.

This case specification enables modeling the 1600MW of Custer generation in blocks of 450, 350, 350 and 450 MW, respectively.

6.12.2 Contingency Analysis Results for 450MW

Contingency analysis at the 450MW level identifies the following severe contingencies:

Clatsop to Astor TP transformer presents overloads for the following single outages:

Contingencies that Overload the Clatsop to Astor TP Transformer				
Label	Category	Value	Limit	Percent
L40669LONGVIEW-47287NYSTAPC4	Branch MVA	139.61	120.00	116.35
L40041ALLSTON-47287NYSTAPC4	Branch MVA	137.98	120.00	114.98
L40041ALLSTON-40339DELENAC1	Branch MVA	136.95	120.00	114.12

However, the TLR sensitivities for Custer generation for these contingencies are small. Thus, the upgrade of the Clatsop to Astor TP transformer is left for a future state.

The Bingen to Condipth 69kV line is overloaded with the following contingencies:

Contingencies that Overload Bingen to Condipth				
Label	Category	Value	Limit	Percent
L40013ACTON-40139BONNVILEC1	Branch MVA	50.84	37.00	137.40
L40013ACTON-40187CASCDLKC1	Branch MVA	50.72	37.00	137.07
L40187CASCDLK-40541HOODRVRC1	Branch MVA	49.98	37.00	135.07

The Baker to Sedro Circuit 2 contingency creates an overload of 30% in Baker SW to Sedro.

Overloads appear South of Portland, including the Alvey to Dixonville, Alvey to Marion and Pearl to Marion.

In the Seattle area, the Sedro to Horse Ranch outage creates severe violations. These preliminary results indicate the need of system expansion for single contingency at the 450MW level of Custer generation.

6.12.3 Comparative Contingency Analysis

The following table illustrates the behavior of overloads for different levels of generation at Custer. The contingency records were sorted based on the maximum change in overload from the 1150MW to the 1600MW level. This allows the visualization of the contingencies that become severe with an increase in generation. Only contingencies that were not present in the 450MW level are listed.

Contingencies that become severe with Custer Generation					
Custer Generation Level	=450	=800	=1150	=1600	
Contingency Label	Max %	Max %	Max %	Max %	Diff
L42321HRNCHTAP-42100SEDROC1		106.70	113.80	121.30	7.50
L40821PAUL-40869RAVERC1			101.90	106.80	4.90
L40045ALLSTON-41804NAPAVINEC1			101.60	106.30	4.70
L40045ALLSTON-40821PAULC2			101.60	106.20	4.60
L40323CUSTERW-40749MONROEC1			104.90	109.40	4.50
L40767MURRAY-42103SEDRONTC1		103.00	108.30	112.70	4.40
L40045ALLSTON-40601KEELERC1			101.60	105.70	4.10
L40323CUSTERW-40749MONROEC2			101.80	105.70	3.90
L40869RAVER-41051TACOMAC1			101.70	105.40	3.70
X42100SEDRO-42101SEDROC1		101.30	104.10	107.70	3.60
L41804NAPAVINE-40821PAULC1			101.70	104.60	2.90

The table shows that the overloads become worst as Custer generation increases.

6.12.4 Proposed System Expansion

Expansion at the 450MW level requires sectionalizing the Sedro to Custer 230kV line in order to send all the extra flow directly through the 500kv system, relieving the Sedro to Horse Ranch and Sedro to Murray 230kV lines. We recall that. State 8 included Sedro generation, which if connected directly to the Sedro substation created considerable overloads in the 230 and 115kV systems in the Sedro area for several contingencies. This occurred even with the third Custer to Monroe circuit from state 4 in place. These overloads motivated moving the Sedro generation to 40/87 junction on one of the Custer to Monroe circuits.

Figure 12.a shows the base case conditions with 600MW generation at Sedro and 1650 MW at Custer (600 of state 3, 600 of state 4 and 450 of the first block of Custer generation at state 12)

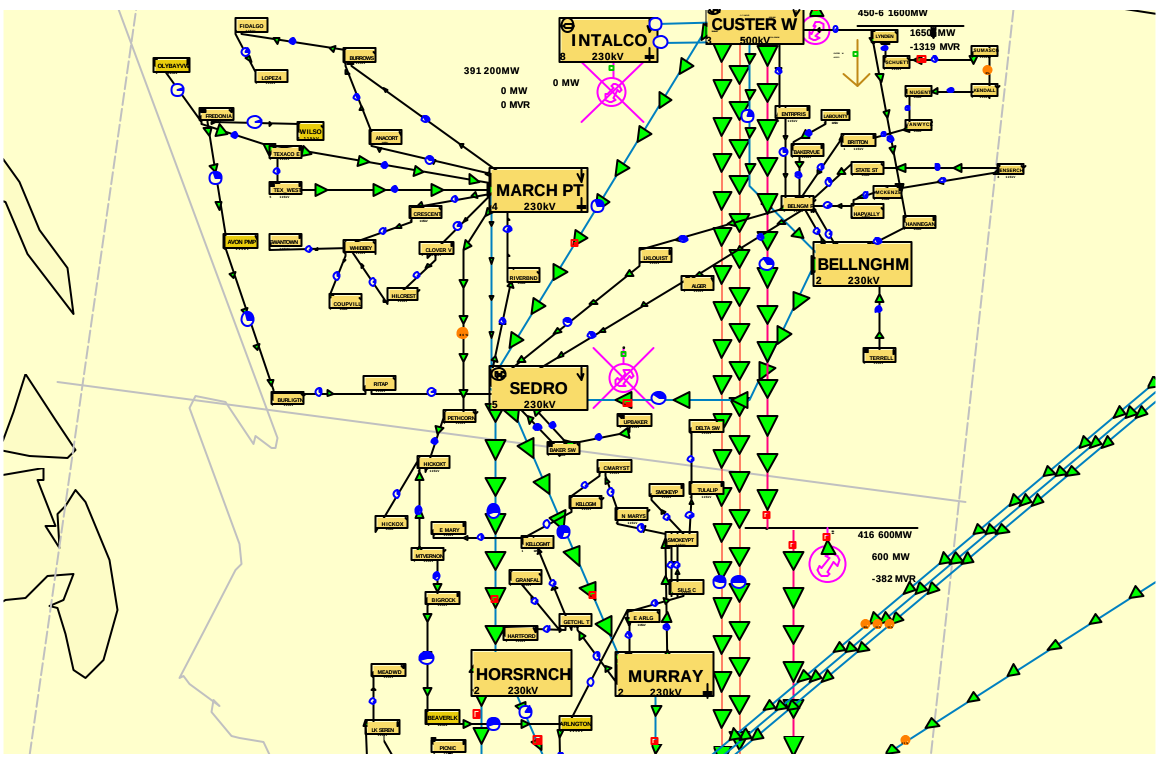


Figure 12.a: Base Case conditions for the 450MW level at Custer (state 12)

Note the pie charts in the lines indicate the percentage flow with respect to the rating. So, for instance the Sedro (NT) to Murray line has a 75% loading in this condition.

When the Sedro to Horse Ranch is outaged we obtain the condition shown in the following Figure.

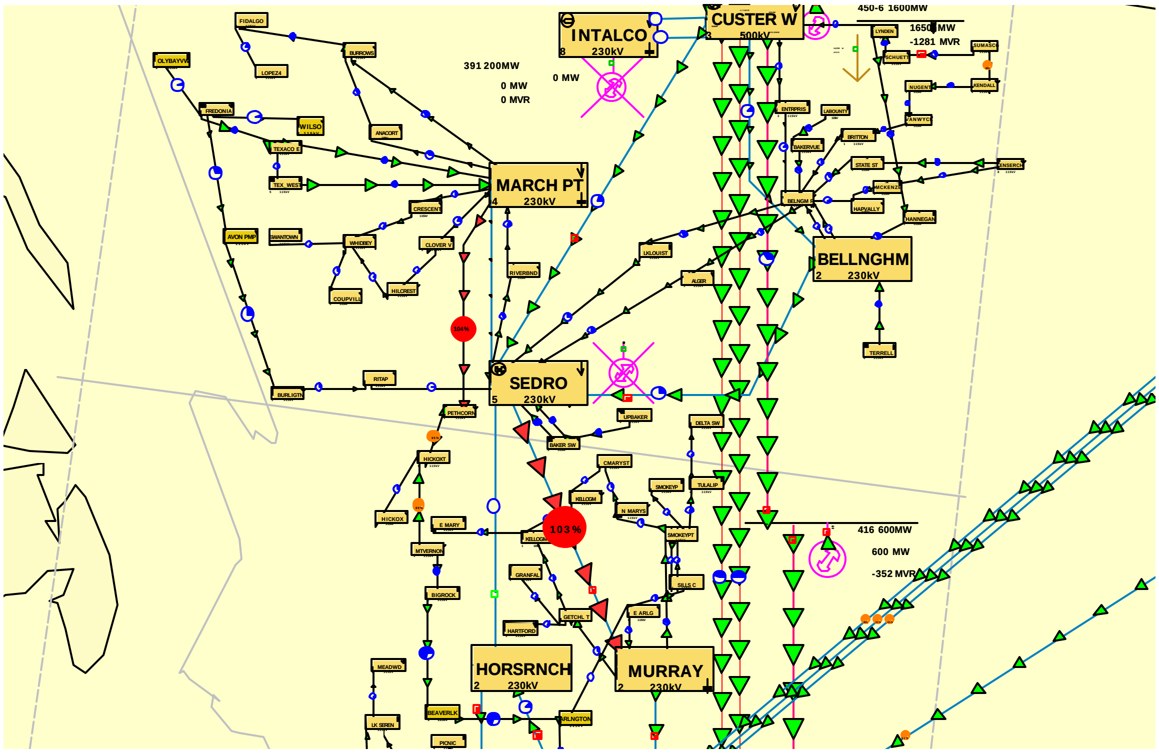


Figure 12.b: System Conditions for Sedro to Horse Ranch Outage

Because of this contingency, the Sedro NT to Murray and March PT to Pethcorn lines are overloaded and there is heavy loading in other lines. This occurs because the TLR of the overloaded lines is too high with respect to Custer generation. Without RAS, the system expansion has to solve this situation. This problem is difficult to solve because there are almost concurrent overloads and there are many elements involved.

A second Sedro to Murray circuit was tested. The problem with this alternative is that this reduces the impedance of the 230kV system with respect to the 500kV system and consequently there is a increased flow in the 115kV network. This is close to cause overloads in the base case.

The following condition is obtained by opening the Custer to Sedro lines:

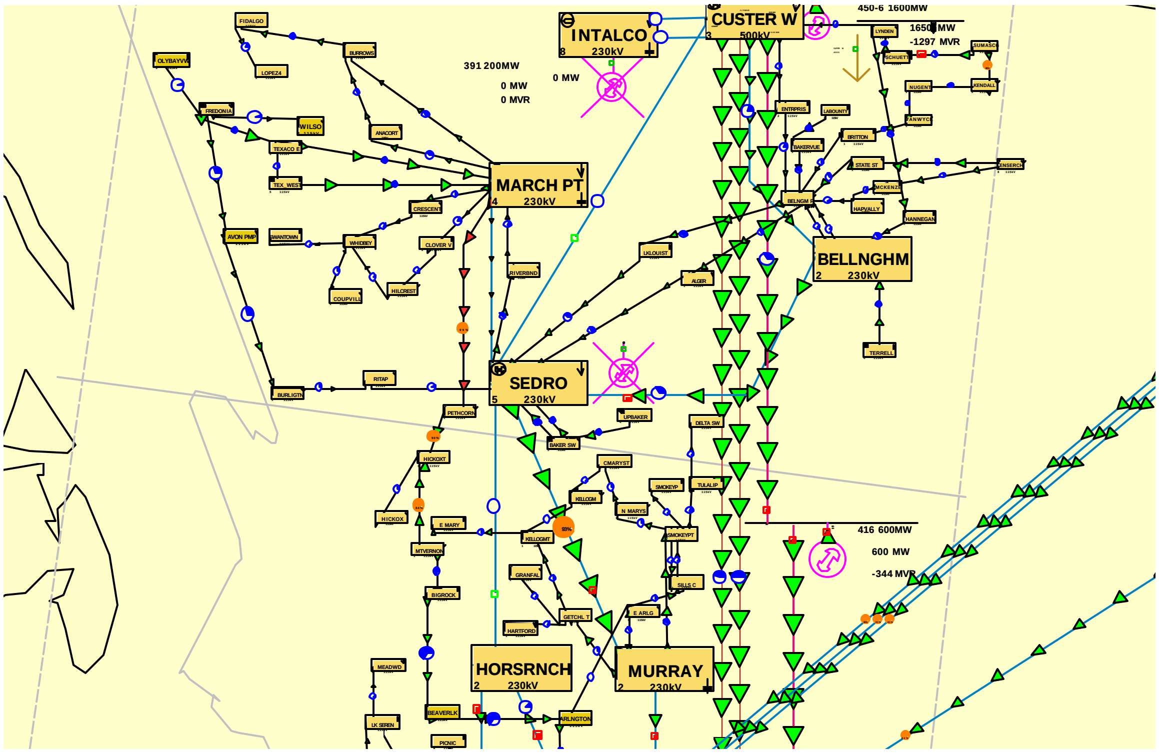


Figure 12.c: Outage Conditions with Custer to Sedro Opened

In this conditio n, the lines are close to overload but there are no overloads in the system. Note that this is for Custer at the 450MW level. If the generation at Custer increases (second, third and fourth blocks of Custer state 12), then additional system expansion is needed. Since the impedance of the Custer to Sedro line is small, it tends to attract considerable flow. Thus, for the 2800 aggregate level at Custer (States 3+4+12) we still would need to open this line (or extensive expansion at the 230 and 115kV levels. This alternative does not create additional violations in the 115kV system for an outage of the Sedro to Horse Ranch. The following plot shows the condition for an outage of the Custer to Bellingham.

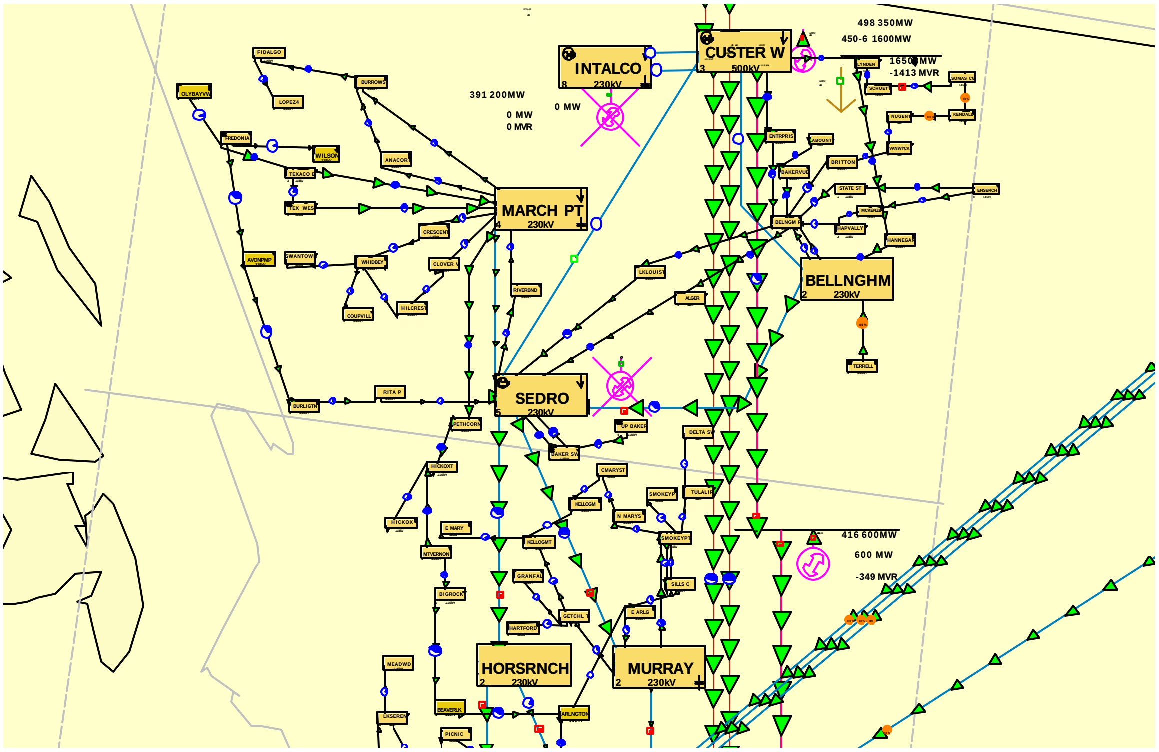


Figure 12.d: Custer to Bellingham Outage

As seen in the figure, this conditions does not present overloads. However, RAS should address the Bellingham to Sedro outage, which does presents overloads.

The Pearl to Marion outage needs to be mitigated, possibly with a double circuit to this line.

As generation at Custer increases to the 800MW level, new violations that must be addressed appear. From the table above, substantial system expansion is required to accommodate 1600MW of transfer from Custer. System expansion would be at least the necessary to carry more than 1000 additional MW virtually from Custer to Big Eddy. This can be done by single 500kV elements Custer to Monroe to Echo Lake to Raver to Paul to Troutdale to Big Eddy, possibly excluding Echo Lake to Raver. A DC project Custer to Celilo carrying at least 900MW is other alternative. This DC link with 1600MW is excessive for this state and may overlap some of the expansion designed in previous states.

Due to the considerable system expansion needed to allocate the generation in this state, the increment of Custer Generation is not considered in the base case of the state 13.

6.13 System State 13: Trojan Generation (170MW) Request 457

6.13.1 Base Case Results

The base case at state 13 is set up as follows:

a) We assume the same imports of state 12: Imports from Montana are changed to be exports of 1000MW. Imports from Idaho are changed to be exports of 1000MW. Exports to California are increased from the 3900MW level to 4500MW.

b) Imports/exports are balanced by reinserting generation previously displaced. Ingledow to Custer transfer is controlled with the phase shifter at +25 degrees.

c) The generation at Centralia and Chehalis is back in place to model the worst-case condition.

d) Custer generation of state 12 IS NOT in place, since that transfer would require substantial expansion that would deviate the analysis of the impact of Trojan generation.

In the base case, we obtain a violation of less than 1% for the Copco to Weed Jct. This violation occurs in the South part of the I-5 corridor and is due to the increased export to California.

The following figure shows PTDF contouring for a transfer from Trojan to Libby. We see that half of the flow goes in the North direction through Allston to (Chehalis) to Paul to Raver. This may reduce the netting effect of generation in this area. The other half goes towards the South attempting to reach Keeler substation mostly through Allston. Some 230 and 115kV lines in the area increase their flow and most violations will appear in this area.

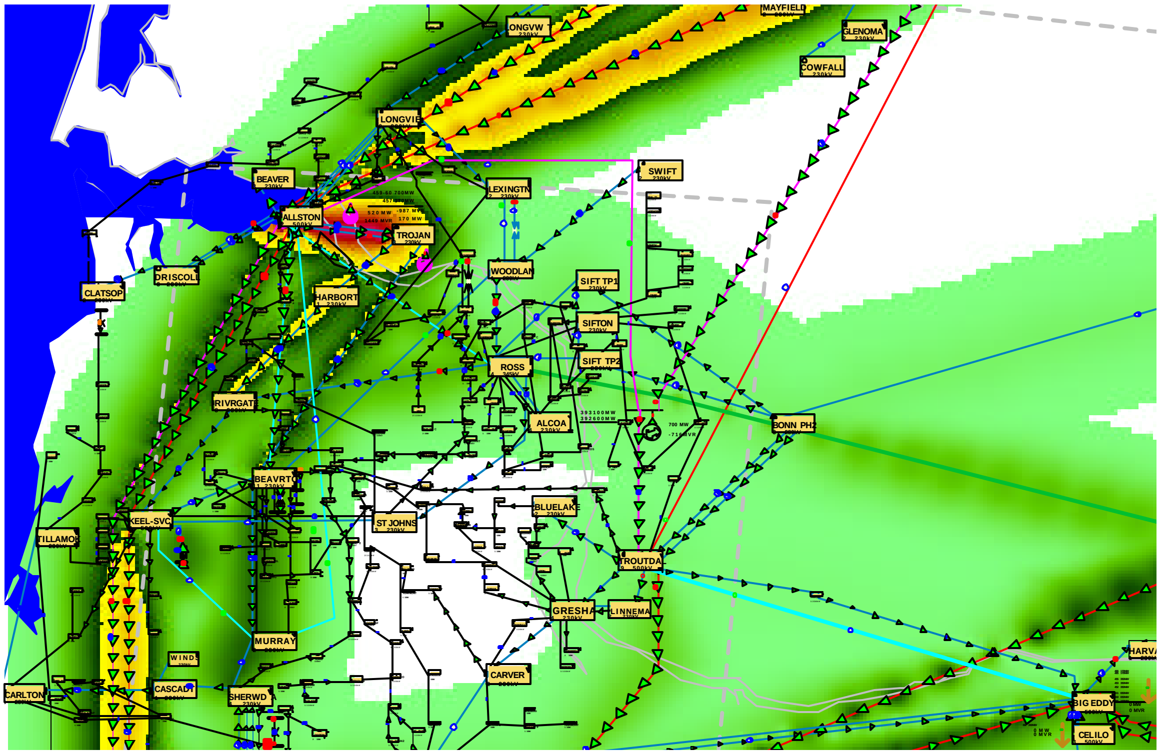


Figure 13.a: PTDF Contouring for Generation at Trojan

6.13.2. Contingency Analysis

An outage of the Longview transformer produces the following violations:

Violations for the Longview Transformer Outage			
Element	Value	Limit	Percent
FROM CLATSOP TO ASTOR TP CKT 1	123.55	120.00	102.96
FROM LEXINGTN TO PACIF WY CKT 1	159.75	155.40	102.80
FROM LONGVIEW TO PACIF WY CKT 1	155.66	155.40	100.16

Although the violations are small, different generation patterns may create overloads up to 23% in the Clatsop to Astor TP transformer.

The Marion to Pearl 500kV line outage cause a small overload in the McLaughlin to Monitor circuit.

The Longview to NysTap Circuit 4 causes 18% overload in the Clatsop to Astor TP 230 to 115kV transformer. The following figures show base case and the mentioned outage condition.

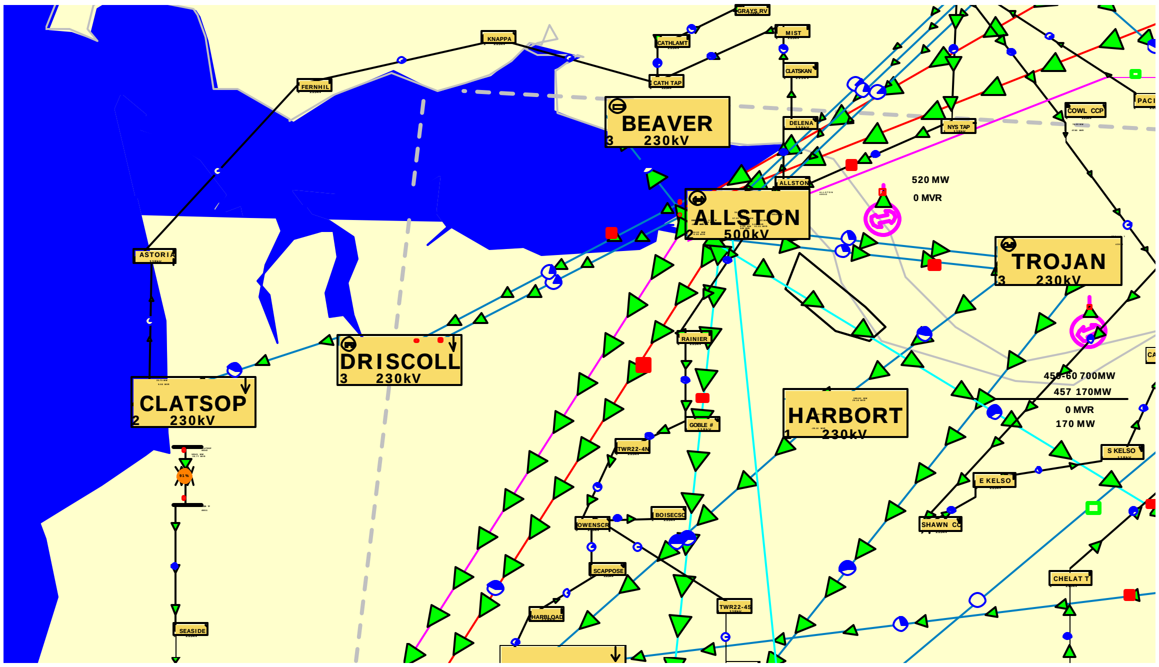


Figure 13.b: Base Case Conditions with 170MW at Trojan

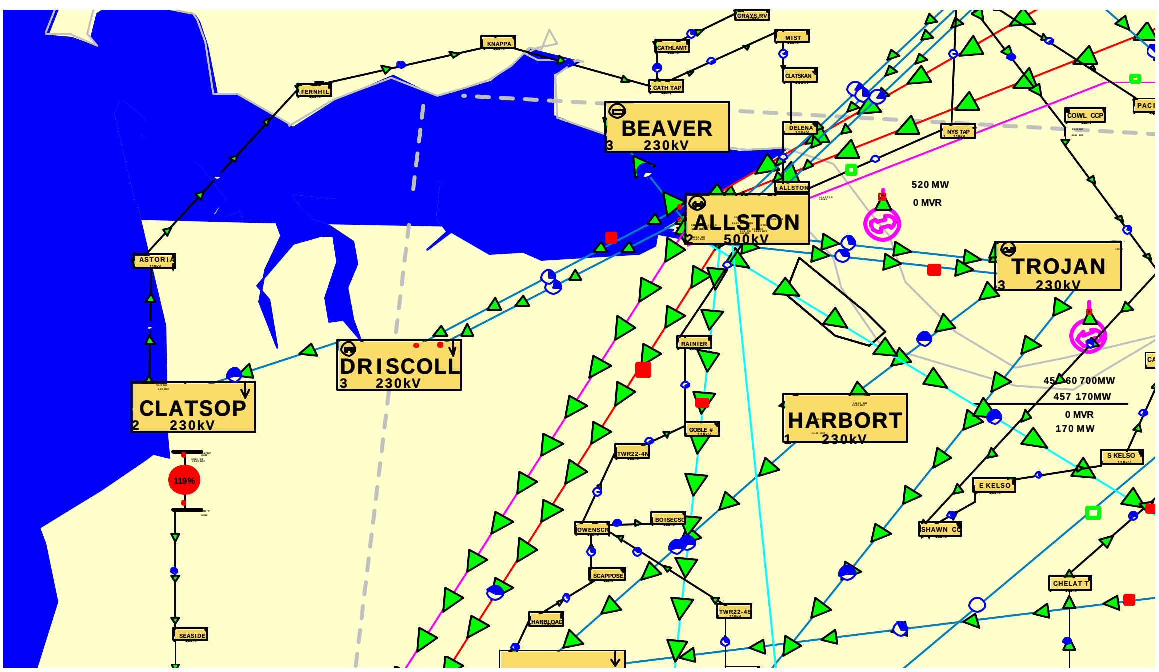


Figure 13.c: Outage to Allston to Nys Tap Outage

The Clatsop to Astor TP element presents additional severe overloads with the following contingencies:

Contingencies for Overloads in the Clatsop to Astor TP Transformer				
Label	Category	Value	Limit	Percent
L40041ALLSTON-40339DELENAC1	Branch MVA	138.72	120.00	115.60
L40041ALLSTON-47287NYSTAPC4	Branch MVA	140.47	120.00	117.06
L40189CATHTAP-40741MISTC1	Branch MVA	130.76	120.00	108.97
L40241CLATSKAN-40339DELENAC1	Branch MVA	137.02	120.00	114.18
L40241CLATSKAN-40741MISTC1	Branch MVA	132.75	120.00	110.63
L40669LONGVIEW-47287NYSTAPC4	Branch MVA	142.11	120.00	118.42

The Clatsop to Astor TP transformer is part of a parallel circuit to Allston-Keeler. The following table shows TLR sensitivities for this transformer for an outage of the Longview to NysTap C4 circuit.

TLR Sensitivities for the Clatsop to Astor TP Transformer							
Contingency: Longview to NysTap C4							
Number	Name	P Sensitivity	Gen MW	Number	Name	P Sensitivity	Gen MW
47260	WAUNA	0.05	27	40841	PORT ANG	0.003	28.6
43017	BEAVER	0.011	360	45039	CENTR G1	0.003	692
43019	BEAVER	0.011	135	41803	CHEH ST	0.003	230
40043	ALLSTON	0.011	520	45041	CENTR G2	0.003	692
40671	LONGVIEW	0.01	567	40947	SATSOP	0.003	1300
40309	COWL CCP	0.009	100	40007	ABERDEEN	0.003	11
43599	TROJAN 1	0.008	170	41801	CHEH G1	0.003	195
40199	CENTRALA	0.006	10	41053	TACOMA N	0.002	250
40821	PAUL	0.003	300	46607	COWLITZ	0.002	100
41802	CHEH G2	0.003	195	40941	SANTIAM	-0.002	600
40947	SATSOP	0.003	1300				

The table shows that the aggregate generation in the sequence contributes to the N/S flow and loading of this element. This transformer is the weakest in the path from Clatsop to Astor TP to Seaside to Cannon B to Nehal TP and to the South, which is loaded up to 30% for the contingency condition. Thus, an upgrade of this transformer is required. We assume an upgrade from 120 to 150MVA. Trojan and Allston generation have a large sensitivity among the new I-5 corridor. Additional generation at Trojan in the next state will further increase the loading in this element.

There are other minor violations in the system. Most of them occur due to putting back in service generation at Centralia and Chehalis, as well as the new generation in the I-5 corridor, in particular Allston and Paul. TLR sensitivities reveal that Trojan generation contributes to these overloads, but is not their main cause. However, this worst-case condition would require additional system expansion.

In order to identify potential hidden problems in the Portland area, different generation patterns including combinations of Paul, Allston and Alcoa generation were tested in this state. No further violations were found for contingency conditions.

6.13.3 Proposed System Expansion

The Astor TP to Clatsop 115 to 230kV is upgraded to the 150MVA level. This follows the same philosophy of a previous upgrade of this element.

6.14 System State 14: Trojan Generation (700MW) Request 459, 460

6.14.1 Base Case Results

The state base case includes 700 additional megawatts. Generation displacement was done at Dworshak. The PTDF distribution is similar to the one of state 13. The base case presents small violations associated to the assumed additional exports to California, which are not considered for system expansion. The results focus on conditions that allow the simulation of additional generation in the Portland area.

6.14.2. Contingency Analysis

The Marion to Pearl 500kV line outage overloads the McLaughlin to Monitor in 5% and the Ostrander to Big Eddy 500kV line in 27%. This condition is illustrated in the following figure.

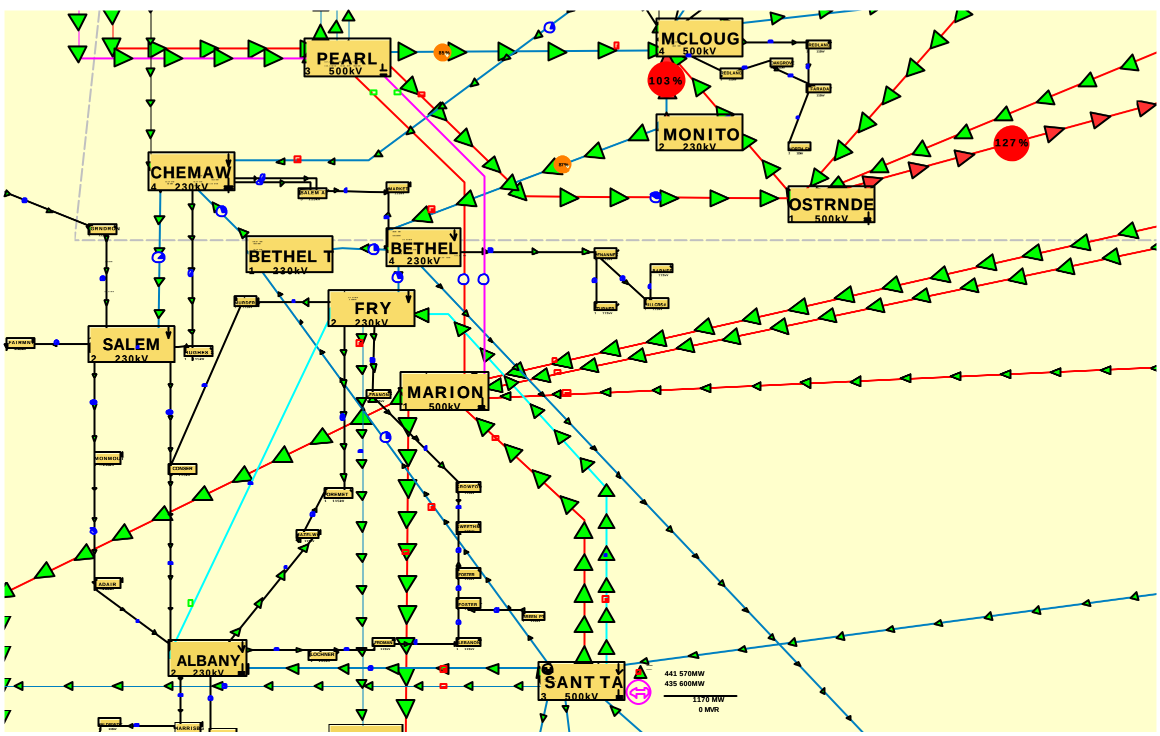


Figure 14.a: Outage to Pearl to Marion

If Santiam generation is not in place, the following overloads are obtained.

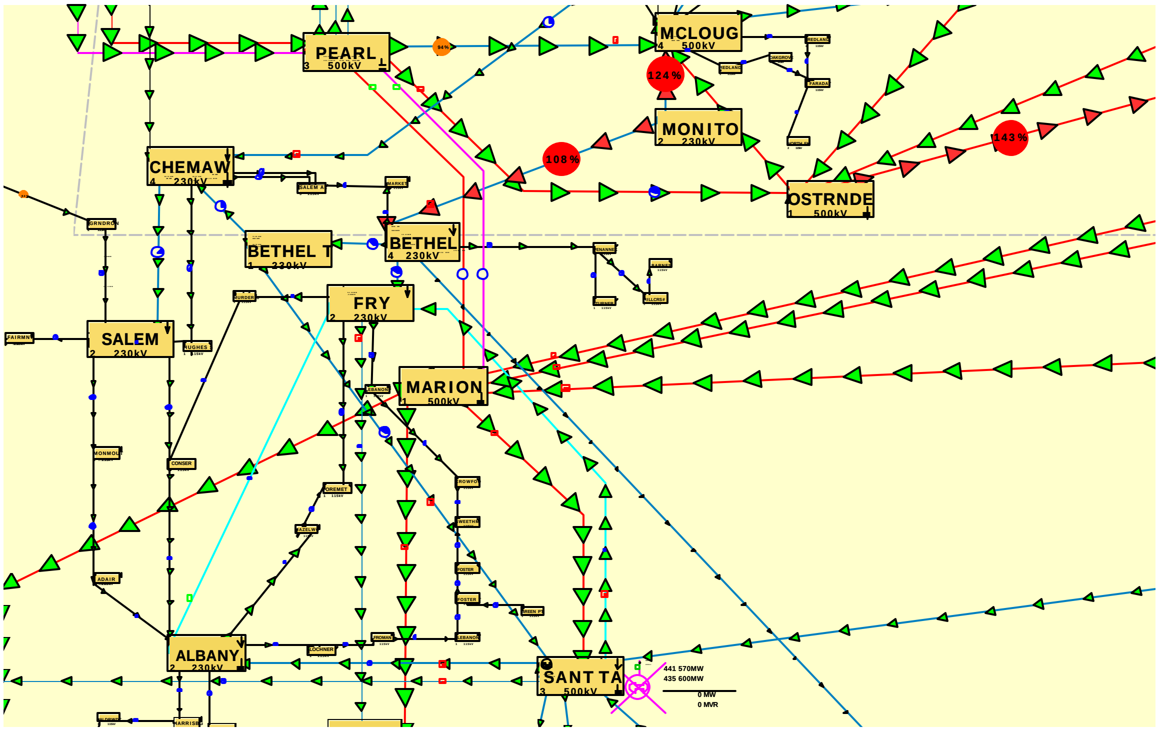


Figure 14.b: Outage to Pearl to Marion without Santiam Generation

Clearly, a backup for the Pearl to Marion line is needed.

The Beaverton to Denny 115kv line presents overloads for the following contingencies:

Contingencies for Overloads in Beaverton to Denny

Contingency Label	Value	Limit	Percent
L43279KINGCITY-43525SHERWDBC1	209.66	197.00	106.43
X41095TROUTDAL-41093TROUTDALC1	207.65	197.00	105.41
L43547STMARYE1-43553STMARYSAC1	205.04	197.00	104.08
L43755CEDARHL#-43547STMARYE1C1	204.99	197.00	104.06
L40601KEELER-40827PEARLC1	200.00	197.00	101.52
L43279KINGCITY-43589TIGARD1C1	199.72	197.00	101.38
L43055BONNYSL-43792WILBRDG#C1	197.81	197.00	100.41
L43055BONNYSL-43755CEDARHL#C1	197.81	197.00	100.41

Sample TLR sensitivities for this element with an outage of the Sherwood transformer are as follows:

TLR Sensitivities for Beaverton to Denny

Contingency: Sherwood Transformer

Number	Name	P Sensitivity	Gen MW	Number	Name	P Sensitivity	Gen MW
43599	TROJAN 1	0.015	870	45041	CENTR G2	0.004	692
40043	ALLSTON	0.013	520	46607	COWLITZ	0.003	100
41801	CHEH G1	0.005	95	41053	TACOMA N	0.003	250
41802	CHEH G2	0.005	95	40323	CUSTER W	0.002	1200
41803	CHEH ST	0.005	230	79401	SEDRO	0.002	600
40821	PAUL	0.004	300	42100	SEDRO	0.002	0
40947	SATSOP	0.004	1300	40941	SANTIAM	0.001	1170
45039	CENTR G1	0.004	692	79400	ALCOAM	-0.006	700

Clearly, Trojan generation creates a considerable additional flow in this element, which must be addressed by system expansion.

The Huber 2 to Tek 1 presents overloads with the following contingencies:

Contingencies for Overloads in Huber 2 to Tek 1

Contingency Label	Value	Limit	Percent
L43348MURRAYH-43541STMARYSC1	191.21	180.00	106.23
X43348MURRAYH-43347MURRAYHC1	189.89	180.00	105.49
L43029BEAVRTON-43347MURRAYHC1	189.53	180.00	105.30

It is interesting to analyze the TLR sensitivities for Huber 2 to Tek 1. The following table shows the sensitivities for the case of a Murray transformer contingency.

TLR Sensitivities for Huber 2 to Tek 1

Contingency: Murray Transformer

Number	Name	P Sensitivity	Gen MW	Number	Name	P Sensitivity	Gen MW
43599	TROJAN 1	0.0157	870	46627	MOSSY RK	0.0075	150
40043	ALLSTON	0.0121	520	41803	CHEH ST	0.0044	230
43019	BEAVER	0.0121	135	41801	CHEH G1	0.0044	195
43017	BEAVER	0.0121	360	41802	CHEH G2	0.0044	195
47260	WAUNA	0.0118	27	40841	PORT ANG	0.0039	28.6
40671	LONGVIEW	0.0115	567	40007	ABERDEEN	0.0039	11
40309	COWL CCP	0.0101	100	40947	SATSOP	0.0038	1300
45287	SWIFT	0.0076	300	45039	CENTR G1	0.0035	692
40199	CENTRALA	0.0075	10	40821	PAUL	0.0035	300
46623	MAYFIELD	0.0075	40	45041	CENTR G2	0.0035	692
47047	GLENOMA	0.0075	30	41053	TACOMA N	0.003	250
40307	COWFALLS	0.0075	17				

We see that for this element the sensitivity of Trojan generation is the highest. This generation increases the flow in 13MW, enough to create the overload. The other generators in the area (Allston) have also an impact in this element.

6.14.3 Proposed System Expansion

The Large North to South flow makes it necessary to create a back up for the Pearl to Marion 500kV link. The second circuit would have the same parameters as circuit 1.

It is important to eliminate the violation in the Beaverton to Denny 115kV line. A new Huber to Tigard 2 115kV line together with an increase of the rating of the Huber to Huber1 link from 197 to 225 MVA achieves this. This rating upgrade is required for the Beaverton to Denny outage. In the base case the new line carries approximately 100MW decreasing the Beaverton to Denny flow from 180 to 120MW. It also relieves the Huber 2 to Tek 1 line from 140 to 120MW approximately. This addition considerably improves the contingency conditions in this area. Finally, the Huber 2 to Tek 1 115kV line is upgraded to the 200MVA level.

7. RAS Analysis

The following analysis looks at how RAS can remove the need for the system upgrades proposed throughout the previous parts of this report. If line overloads can be removed through the use of RAS, then we label the "RAS Alternative Exists" as YES. If RAS is unable to remove an overload, then the "RAS Alternative Exists" is labeled NO. Finally if a very large amount of RAS is needed, and we believe that in general RAS may not always work to remove the overloads, then the "RAS Alternative Exists" is labeled Uncertain.

State 1 Expansion

Upgrade of Dayton 115/59.8 kV transformer from 50 to 60MVA

RAS Alternative Exists: YES

This transformer is overloaded in hundreds of contingencies in State 0. The overload can be removed by opening any one of several 59.8 kV paths to prevent flow through the transformer. We can likely assume that this is already done in the system today.

New 230kV line Allston to Ross

RAS Alternative Exists: YES

The worst line loss here is the Allston – Keeler 500 kV line. The loss of this line removes the 500 kV path around Western Portland and forces large flows through Portland. The worst problems are on the Ross-Woodland 230 kV line, Longview 230/115 kV transformer, and St Marys – Trojan 230 kV line. These overloads can be addressed by adding the Allston-Ross and Allston to St. Marys 230 kV lines. It was found however that RAS involving generation dropping is also able to relieve these problems.

- Longview – 567 MW
- Swift – 299 MW

Therefore, RAS can remove the need for the Allston-Ross 230 kV expansion. Also note that the large load at Longview (344 MW) being out of service further worsens flows through Portland. This can be mitigated by more generation dropping at Allston or Beaver.

New 230kV line Allston to St. Marys

RAS Alternative Exists: NO

The same RAS that removes the expansion for the Allston to Ross 230 kV line can remove overloads at this point in our analysis. However, it will be found later in State 14, that this line becomes necessary. As a result this line will likely be needed.

Upgrade of Longview transformer from 288 to 350MVA

RAS Alternative Exists: NO

Overloads on this branch can be mitigated by RAS involving generation dropping at Longview and to the north (Chehalis, etc..). However, there is a large amount of load at the Longview 230 kV bus (344 MW) which represents a large manufacturer that often goes off-line during times of peak demand. Therefore, it is likely very wise to upgrade this transformer. It continues to show up as a problem throughout the analysis because transformer is right in line with the general North to South flow of the power.

State 2 Expansion

Upgrade of the new Allston to Ross line

RAS Alternative Exists: YES

Again, RAS can remove the need for this line. See State 1 Expansion.

Upgrade of Dayton transformer from 60 to 75MVA

RAS Alternative Exists: YES

Again, RAS that involves opening 59.8 kV paths can remove this overload. See State 1 Expansion.

State 3 Expansion

State 4 Expansion

New Custer to Monroe 500kV circuit.

RAS Alternative Exists: Uncertain

This line is similar to the Allston – Pearl, and Tacoma – Paul 500 kV lines proposed in later states. With the large amount of generation being added at Custer, this line addition will be needed unless an alternative addition such as Custer to Big Eddy is created.

State 5 Expansion

New substation at 2/3 of Paul to Troutdale 500kV

RAS Alternative Exists: NO

We assumed that this was necessary just to connect the new generation to the system. It isn't really a system "expansion". It just involves connecting the new generator to the system.

Upgrade of the 230-500kV Troutdale transformer to 1500MVA.

RAS Alternative Exists: YES

This transformer is rated at 1321 MVA presently. It may be possible to re-rate the transformer or add cooling of some kind to upgrade this rating. Regardless, RAS that drops the generation at ALCOA will always be sufficient to remove the overload.

State 6 Expansion

New circuit Olympia to Satsop

RAS Alternative Exists: NO

The 230 kV lines from Olympia to Satsop overload as soon as the additional 1300 MW of generation is added at Satsop. These overloads are not even under any contingencies, thus this upgrade will be mandatory if a large amount of new generation is connected at Satsop.

Disconnection of Holcomb to Valley T To solve Cosmopolys to Raymond overload

RAS Alternative Exists: Uncertain

Other system upgrades could be proposed, but this line sectionalizing may be the best option to remove these 115 kV overloads.

New Allston to Pearl 500kV line.

RAS Alternative Exists: Uncertain

The loss of the Keeler to Pearl 500 kV line results in numerous overloads in the Portland 115 kV and 230 kV transmission system. These overloads can be mitigated by performing a large amount of RAS generation dropping at the following generators:

- Beaver (43017) – 360 MW
- Beaver (43019) – 135 MW
- Allston (40043) – 520 MW
- Chehallis (41802-41803) – 420 MW

This is a total of 1425 MW of generation dropping. The Allston – St Marys 230 kV transmission line addition (from State 1) was included in this analysis, because it will be found to be needed later in State 14.

State 7 Expansion

No system expansion is needed.

State 8 Expansion

New Tacoma to Paul 500kV line

RAS Alternative Exists:Uncertain

The loss of the Raver – Paul 500 kV transmission line causes numerous overloads in the 230 kV and 115 kV system in Seattle. This is presently a problem that BPA addresses by using RAS that involves up to 2600 MW of generation dropping (200 MW at Fredonia, 150 MW at White Horn, 1650 MW at Chief Jo, and 300 MW each from Mica and Revelstoke in BC Hydro). We are able to remove the overloads caused by the Raver-Paul outage in this case by performing similar generation dropping, however as we continue to put larger amounts of generation to the north of Seattle (Sedro and Custer) this contingency will continue to worsen. It will also worsen if large amounts of Canadian Imports are looked at. Because BPA is already dropping 2600 MW of generation, additional RAS is limited. Therefore, it is likely that a larger project, such as a Custer – Big Eddy 500 kV path (or DC line), may become necessary. This is proposed later in State 12 and 16. A large project such as this would greatly reduce problems caused by the Raver-Paul outage. If such a project is looked at, the RAS presently executed under the Raver-Paul outage may become unnecessary.

If a large project like the path from Custer – Big Eddy is not considered, then a new line from Tacoma to Paul may be required.

New Monroe to Echo Lake 500kV circuit.

RAS Alternative Exists: YES

The loss of the Monroe – Echo Lake and Snok Tap – Echolake lines causes overloads in Seattle. Specifically it overloads the two 230 kV circuits from Maple Valley to Snoking 230 kV. This is a problem in BPA's existing system, and is overcome by RAS that drops 950 MW of generation (200 MW at Fredonia, 150 MW at White Horn, and 300 MW each from Mica and Revelstoke in BC Hydro). We are able to remove the overloads here in the same way. Unlike the previous addition, there is more room to perform a greater amount of RAS generation dropping as well. Thus it is possible that this is upgrade will be unnecessary regardless of a larger Custer – Big Eddy project.

State 9 Expansion

No new expansion needed

State 10 Expansion

New Santiam to Fry 230kV line

RAS Alternative Exists: YES

The loss of the Marion to Alvey 500 kV transmission line results in an overload on the Albany to Hazelwood 115 kV transmission line. Several other line outages also cause trouble on this 115 kV line. Inserting a new 230 kV line from Santiam to Fry provides an alternative path for the Santiam generation generation, however an alternative RAS which removes the overload on the Albany – Hazelwood line is to open the Oremet – Fry 115 kV line. This reduces the line loading on Albany – Hazelwood down to 90%. Thus RAS can remove this line overload.

New PShift Lexington to Woodland & Cardwell to Merwin

RAS Alternative Exists: YES

These phase shifters reduce flows from North to South through Ross, however generation dropping RAS is also able to remove overloads on this path. This was demonstrated during State 1 and 2 as well. Thus RAS can remove the need for this addition.

Upgrade of Big Eddy to Ostrander to the 1500MVA

RAS Alternative Exists: YES

The loss of the existing Pearl-Marian 500 kV path causes a large overload on the Ostrnder-Big Eddy 500 kV line under this state. This overload can be removed however by dropping any one out of the following three generators.

- Centr G1 (45039) – 692 MW
- Centr G2 (45041) – 692 MW
- Alcoa (79400) – 700 MW

This requires 700 MW of generation dropping, but sufficiently reduces flows on the Ostrnder – Big Eddy 500 kV line.

State 11 Expansion

New Santiam to Fry 230kV line w/rating over 600MVA

RAS Alternative Exists: YES

The loss of the Marion to Alvey 500 kV transmission line results in an overload on the Albany to Hazelwood 115 kV transmission line. Several other line outages also cause trouble on this 115 kV line. Inserting a new 230 kV line from Santiam to Fry provides an alternative path for the Santiam generation generation, however an alternative RAS which removes the overload on the Albany – Hazelwood line is to open the Oremet – Fry 115 kV line. This reduces the line loading on Albany – Hazelwood down to 90%. Thus RAS can remove this line overload.

Upgrade of the Keeler 230 to 115kV transformers

RAS Alternative Exists: YES

The loss of the circuit 2 transformer results in an overload on the circuit 1 transformer even in the original system, with no generation added. This overload worsens as generation is increased to the north of Keeler. The overload can be mitigated by line sectionalizing RAS however. Opening the Keeler – FOR GROV 115 kV transmission line and the Keeler – FOR GR T, 115 kV transmission line relieves this overload. Furthermore, because this RAS scheme involves only lines connected at the Keeler substation, then RAS may be easier to implement.

State 12 Expansion

Line Custer to Sedro 230kV must be sectionalized.

RAS Alternative Exists: NO

As explained in the report, the large amount of generation added at Custer needs to pushed to the South on the 500 kV system. Opening the Custer – Sedro 230 kV line prevents problems to the immediate South of Custer on the 230 kV system.

New 500kV path Custer to Big Eddy or DC project Custer to Celilo with 900MW

RAS Alternative Exists: NO

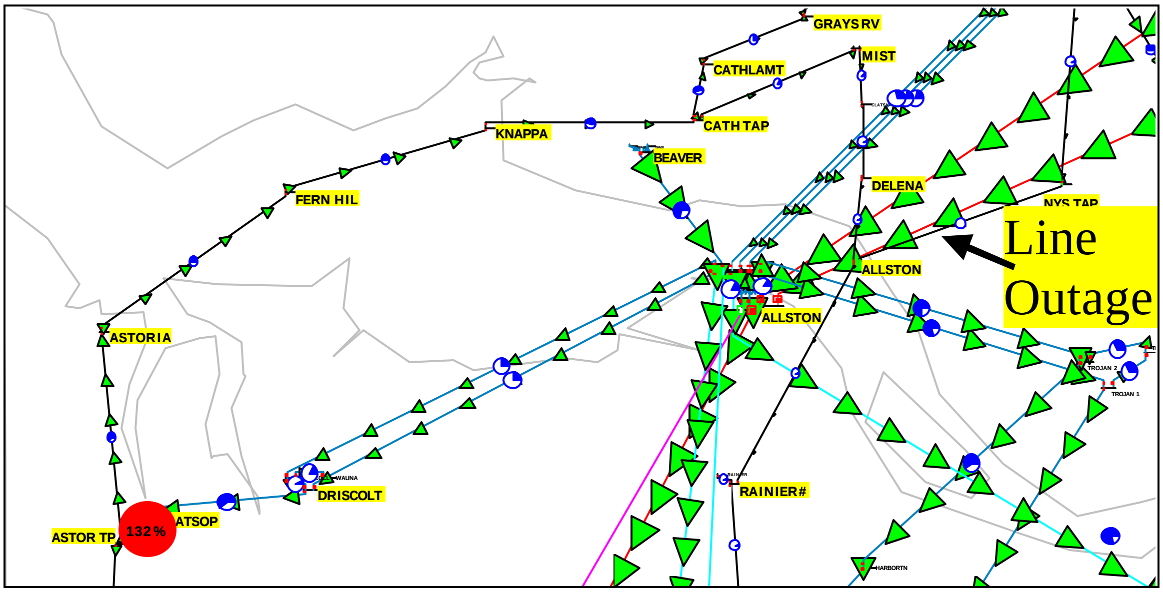
This is a huge amount of generation to add at Custer. A large project such as this will be required if a large amount of generation is added at Custer.

State 13 Expansion

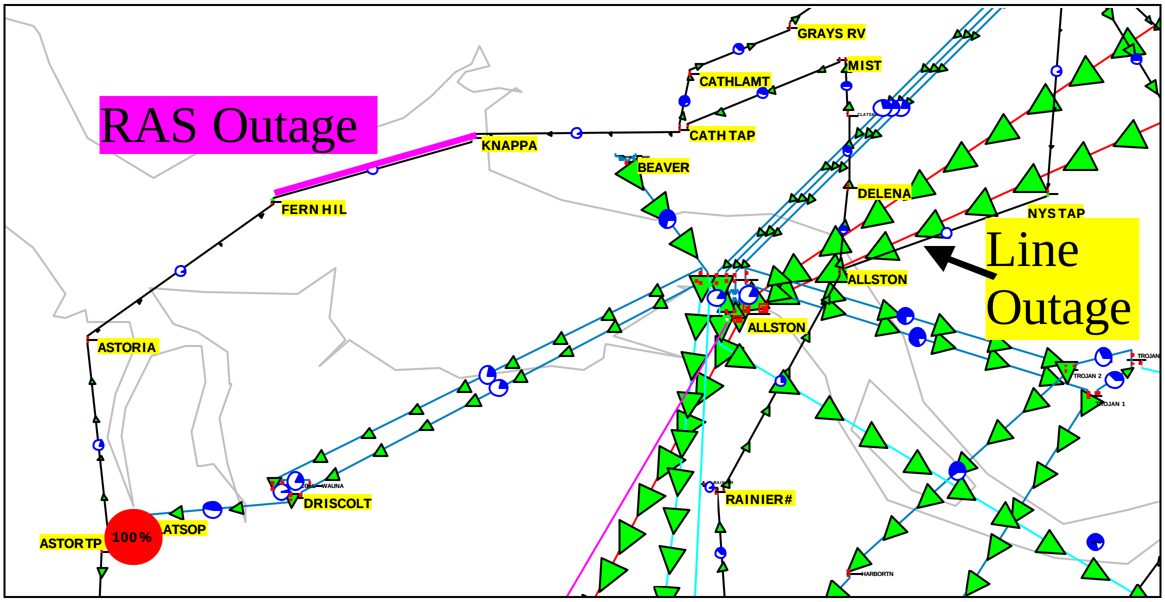
Upgrade of the Clatsop to Astor TP to 150MVA

RAS Alternative Exists: NO

The loss of the Allston – NYS Tap 115 kV branch results in an overload on the Clatsop to Astor TP 230/115 kV transformer. This existing rating of this transmission line is 120 MVA. The overload condition is shown in the next figure. Obviously, upgrading the transformer to 150 MVA will remove this overload.



As an alternative, RAS could be put in place which opens the FERN HIL to KNAPPA 115 kV transmission line when the Alston - NYS Tap 115 kV line is outaged. This results in the flows shown in the next figure.



State 14 Expansion

New Allston to Pearl must be in place (s-6)

RAS Alternative Exists: Uncertain

The loss of the Allson-Keeler 500 kV line causes numerous overloads on the underlying 230 kV system in Portland. Performing a large amount of generation dropping RAS does relieve these overloads however. Dropping the following generation relieves the overloads seen.

- Beaver (43017) – 360 MW
- Beaver (43019) – 135 MW
- Trojan 1 (43599) – 870 MW
- Allston (40043) – 520 MW
- Chehallis (41801-41803) – 620 MW

This requires 2505 MW of generation dropping, so is obviously a very severe action, but one that is able to remove the overloads. (Note, this level of generation dropping was found to be sufficient to remove overloads if the new 1170 MW of generation at Santiam to the South of Portland is out of service as well.) One new line addition that was found to be necessary at this time however was the 230 kV line from Allston to St Marys. Previously, in State 1, this upgrade had been proposed by was dismissed because RAS could relieve the problem. After having added all this generation however, sufficient RAS no longer exists to remove the need for this 230 kV line, thus the Allston to St Marys 230 kV line will be a required upgrade.

New 500kV circuit Pearl to Marion

RAS Alternative Exists: YES

The loss of the existing Pearl-Marian 500 kV path causes a large overload on the Ostrnder-Big Eddy 500 kV line under this state. This overload can be removed however by dropping two out of the following three generators.

- Centr G1 (45039) – 692 MW
- Centr G2 (45041) – 692 MW
- Alcoa (79400) – 700 MW

This requires 1400 MW of generation dropping, but sufficiently reduces flows on the Ostrnder – Big Eddy 500 kV line.

Upgrade of the Huber 2 to Tek 1 to 200MVA

RAS Alternative Exists: Uncertain

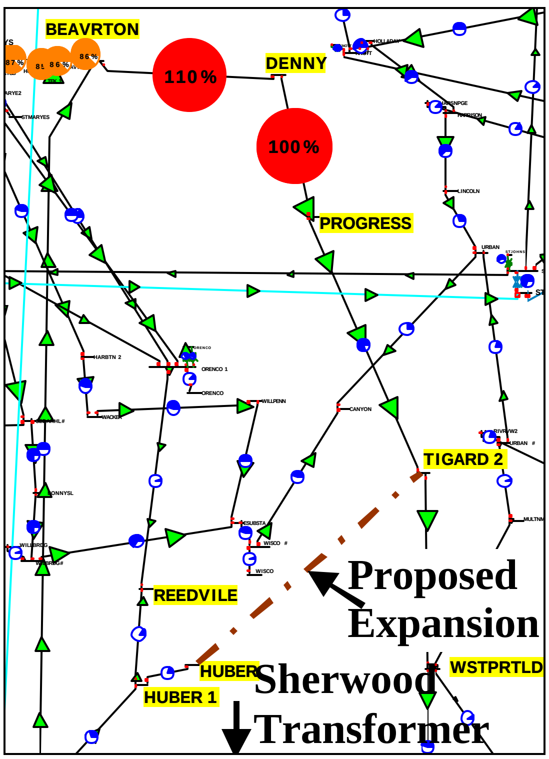
This line is part of the 115kV radial path from STMARYSB(43555) – HUBER 2(43707) – TEK 1(43741) – BEAVTN #(43752) – BEAVRTON(43029) . The Huber 2 to Tek 1 transmission line is rated at 180 MVA, while the other three lines that form this path are all rated at 197 MVA. The line flows reach 191 MVA under the worst contingencies, so upgrading to the same level as the other segments in this path is adequate to remove the overload. RAS can be designed to remove the need for this upgrade, but it may be easier to just upgrade this line. Regardless, one should at least look into upgrading this segment.

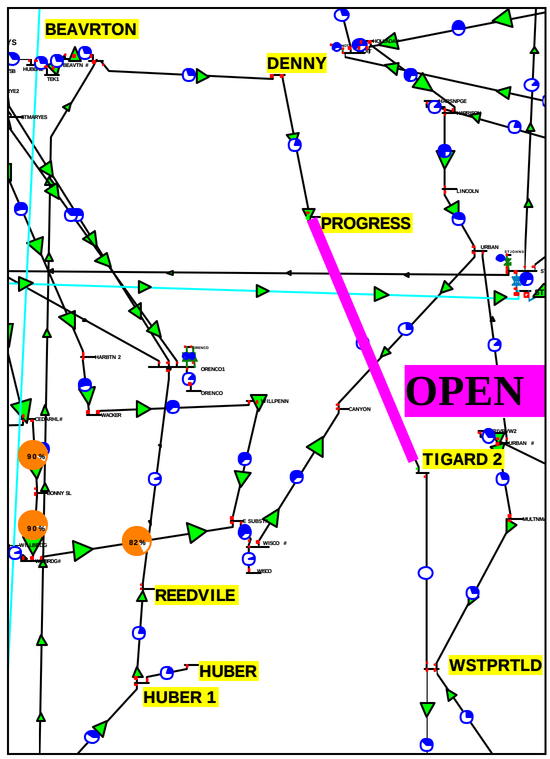
New 115kV line Huber to Tigard 2

Upgrade of the Huber to Huber 1 to 225MVA

RAS Alternative Exists: YES

The loss of the Sherwood 230/115 kV transformer results in an overload on the Beaverton to Denny 115 kV transmission line. This is shown in the figure on the left. The proposed expansion that eliminates this overload was the addition of a 115 kV path between Huber and Tigard2. An alternative RAS that removes the need for this expansion is to open the Progress – Tigard2 115 kV line path under the Sherwood contingency. This is shown on the figure on the right.





8. Addendum for State 11

In the report, State 11 represented the increased generation at Santiam from the 600 MW of State 10 up to a total of 1170MW. After completing the report, it was determined that the additional 570 MW should also be considered under connection at Lane in addition to Santiam. The initial report with all generation connected to Santiam found two necessary upgrades.

1. Upgrade the Keeler 230 – 115kV transformers
2. Upgrade the Santiam – Fry 230 kV line from 400 MVA to 600 MVA

This addendum looks at connecting the generation to Lane instead of Santiam. Analysis proceeded identically to that shown in the initial report, except that the 570 MW of generation was connected at the Lane 500 kV bus instead of Santiam. The results of contingency analysis with 570 MW of generation connected to the Lane 500 kV bus were largely the same as for generation placed at the Santiam 500 kV bus. No additional problems were seen, and the upgrade of the Keeler transformers was still found necessary. However, the upgrade of the Santiam – Fry 230 kV line was found to be unnecessary.

Thus, this addendum finds that as more generation is connected to the Lane 500 kV bus, then the upgrade of the Santiam – Fry 230 kV line from 400 MVA to 600 MVA because of State 11 may be unnecessary. Note that State 10 is still valid however, and the addition of the line rated at 400 MVA as necessitated by State 10 is still needed.